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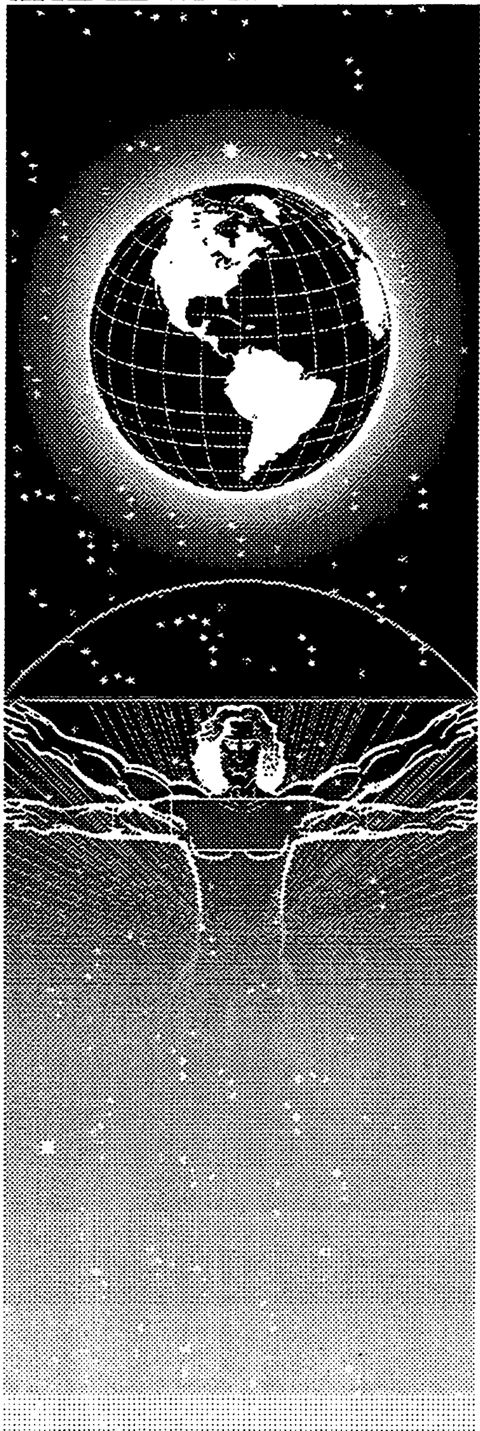

UNITED STATES AIR FORCE RESEARCH LABORATORY

INTERLABORATORY STUDY (ILS) ON THE STANDARD TEST METHOD FOR MEASURING GRID LINE SLOPE (GLS) IN AEROSPACE TRANSPARENCIES

Alan R. Pinkus
Harry L. Task

HUMAN EFFECTIVENESS DIRECTORATE
CREW SYSTEM INTERFACE DIVISION
WRIGHT-PATTERSON AFB OH 45433-7022

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Human Effectiveness Directorate
Crew System Interface Division
2255 H Street
Wright-Patterson AFB OH 45433-7022

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FOR THE COMMANDER

MARIS M. VIKMANIS
Chief, Crew System Interface Division
Air Force Research Laboratory

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Alan R. Pinkus
Harry L. Task

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13. ABSTRACT *(Maximum 200 words)*

When an observer looks through an aerospace transparency, relative optical distortion may result, specifically in thick, highly angled, multi-layered plastic parts. Distortion occurs in all transparencies but is especially critical to aerospace applications such as combat and commercial aircraft windscreens, canopies and cabin windows. This is especially true during certain operations such as takeoff, landing and aerial refueling. It is critical to be able to quantify optical distortion for procurement activities. The test method covers apparatus and procedures that are suitable for measuring the grid line slope (GLS) of transparent parts including those that are small or large, thin or thick, flat or curved, or already installed. This ILS determined the test method's measurement precision.

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1. TITLE
INTERLABORATORY STUDY (ILS) OF THE STANDARD TEST METHOD FOR MEASURING GRID LINE SLOPE (GLS) IN AEROSPACE TRANSPARENCIES

Committee F-7 on Aerospace and Aircraft Enclosures
Subcommittee F-7.08 on Transparent Enclosures and materials
RR: F-7 XXXX*
* number will be assigned at ASTM headquarters.

2. INTRODUCTION

When an observer looks through an aerospace transparency, relative optical distortion may result, specifically in thick, highly angled, multi-layered plastic parts. Distortion occurs in all transparencies but is especially critical to aerospace applications such as combat and commercial aircraft windscreens, canopies and cabin windows. This is especially true during certain operations such as takeoff, landing and aerial refueling. It is critical to be able to quantify optical distortion for procurement activities. The test method covers apparatus and procedures that are suitable for measuring the grid line slope (GLS) of transparent parts including those that are small or large, thin or thick, flat or curved, or already installed. This ILS determined the test method's measurement precision.

3. TEST METHOD

See ASTM F733-90 Standard Practice for Optical Distortion and Deviation of Transparent Parts Using the Double-Exposure Method

4. LIST OF PARTICIPATING LABORATORIES

Laboratories #1 through 3: Jul 1999
AFRL/HECV
2255 H St. Room 300
Wright-Patterson AFB, OH 45433-7022
937-255-8767

Laboratories #4 and 5: Aug 1999
Sierracin/Sylmar
12780 San Fernando Rd.
Sylmar, CA 91342
818-362-6711

Laboratories #6 through 9: Oct 1999
Pilkington Aerospace
12122 Western Ave.
Garden Grove, CA 92641
714-893-7531

Laboratories #10 through 13: Aug 1999
Texstars, Inc.
1170 108th St.
PO Box 534036
Grand Prairie, TX 75053
214-647-1366

Laboratories #14 through 17: Aug 1999
PPG Industries, Inc.
PO Box 2200
Huntsville, AL 35804
256-859-2500

Laboratories # 18 and 19: Dec 1999
Aero Hamble, Ltd.
Kings Ave, Hamble-le-Rice
Hampshire SO31 4NF
United Kingdom
+44 (0) 1703 453371

5. INTERLABORATORY TEST PROGRAM INSTRUCTIONS

Cover letter for test instructions to participating laboratories:

Subject: ASTM Interlaboratory Study (ILS) for Measuring Grid Line Slope of Transparent Parts
To: Participating Organization
From: Alan Pinkus
AFRL/HECV, 2255 H St. Room 300
Wright-Patterson AFB, OH 45433-7022

Dear Colleague,

As part of ASTM Committee 7.08 standards writing activity, we are conducting an ILS in order to ascertain the precision of Standard Practice for Optical Distortion and Deviation of Transparent Parts Using the Double-Exposure Method F733-90. Since this practice has a numerical result, it should actually be a

standard test method which then requires a precision statement. After the ILS, F733-90 will be updated to reflect current art in this area with the inclusion of a precision statement.

Your participation in this study is greatly appreciated. No data will be released with any company or individual identification labels. The data in the ILS report to ASTM are given generic labels and the final precision statement uses only summary statistics as outlined in ASTM E691 and E 177. If there are any questions, please do not hesitate to ask either Alan Pinkus (937-255-8767) or Lee Task (937-255-8166).

Sincerely,

Alan Pinkus, Ph.D.

Test Instructions:

The investigator completes the background information on the data sheet.

There are 2 practice curves [Appendix A(1)] followed by 31 test patterns. The first 21 are numbered, computer generated curves [Appendix A(2), seven curves are repeated three times each] and the last 10 are actual photos through aircraft windscreens [see Appendix B, Sections (1) and (2)]. Each numbered photo also has its own copy.

Align and affix a practice computer generated curve onto the measurement surface. Use the straight (lower) reference line for alignment. Practice measuring grid line slope (GLS), using your current method, as many times as needed until you are comfortable working with this type of curve. If your method will not accommodate this type of curve (i.e., no grid lines present), use the clear grid [Appendix A(3)] if necessary for measurement. You may record your practice results on the data sheet in the lower right corner.

Measure the computer generated curves 1 through 21, recording the GLS values (expressed as a ratio, 1 in XX) on the data sheet. Use your current GLS measurement method (as you described on the data sheet).

Measure photos 22 through 31. First measure the GLS on a numbered photo. The measured grids can be either vertical or horizontal. Indicate the area you measured by circling it with a grease pencil on the appropriate copy. Record the grid line slope (GLS) values and its orientation (H = horizontal; V = vertical) on the data sheet. Use your current GLS measurement method (as you described on the data sheet).

Return data sheet and test set to investigator.

Sample Data Sheet:

ASTM GLS Interlaboratory Study Data Sheet					
Name:					
Date:					
Organization:					
Data Set:					
Brief description of measurement equip. and technique used:					
Sample #	GLS		Sample #	GLS	H or V
1	1 in		22	1 in	
2	1 in		23	1 in	
3	1 in		24	1 in	
4	1 in		25	1 in	
5	1 in		26	1 in	
6	1 in		27	1 in	
7	1 in		28	1 in	
8	1 in		29	1 in	
9	1 in		30	1 in	
10	1 in		31	1 in	
11	1 in				
12	1 in		Practice	GLS	
13	1 in		1	1 in	
14	1 in		2	1 in	
15	1 in		3	1 in	
16	1 in		4	1 in	
17	1 in		5	1 in	
18	1 in		6	1 in	
19	1 in		7	1 in	
20	1 in		8	1 in	
21	1 in		9	1 in	
			10	1 in	

6. DATA REPORT FORMS

See Appendix C.

7. STATISTICAL DATA SUMMARY

Nineteen evaluators participated in this ILS, but one evaluator was removed due to irregularities in his data recordings. Results from eighteen evaluators were used to measure ratios of windscreen distortion. Seven of the evaluators used the drafting machine procedure to measure ratios, while the other 11 used the manual procedure. In Part 1, seven computer generated Gaussian curves of known GLS [see Appendix A(2)] were given to the evaluators for measurement. Each curve was measured three times by each evaluator. Evaluators were instructed to measure the curves using their standard, in-house measurement technique. The Gaussian curves were generated having known slopes. Use of these curves represented a well controlled set of conditions for GLS measurements. In Part 2, ten distortion photographs were taken through actual aircraft windscreens following the procedures outlined in the test method, using a Type 2 grid board. Five of the photographs had undistorted grid reference areas [Appendix B(1)] and five had no undistorted reference areas [see Appendix B(2)]. All curves and photographs were randomly presented. Appendices A(4) and B(3) contain the reference keys. These photographs were given to the evaluators for GLS measurements. The evaluators were again instructed to measure the photographs using their standard, in-house measurement technique. Since the photographs were only measured once, there are no repeatability data from Part 2 of the study, only reproducibility data.

Part 1 - GLS of Gaussian Curves

For the Part 1 analysis, *ratio* refers to a known ratio the evaluators were attempting to measure and *measured ratio* refers to the evaluator's measurement. Each evaluator measured each ratio three times yielding 21 measured ratios per evaluator. Table 1 contains the percent of the total evaluator measurements (18 evaluators by three repetitions) that were equal to the ratio. There were 378 measurements for Part 1.

Table 1 Percent of Evaluator Measurements (n = 54) Equal to the Ratio

Ratio (1 in XX)	Percent = Ratio
2	80
3	70
8	48
10	24
12	24
16	11
20	11

There were two main questions of interest. First, were there differences in the *mean measured ratio* between the drafting machine and manual procedures? Second, were there differences in the *variability* of the measured ratios between the drafting machine and manual procedures?

As seen from Table 1, there is little use in analyzing measured ratios at 1 in 2 and 1 in 3 since the vast majority of measured ratios were equal to the ratio (analysis for 1 in 8 may also be suspect with 48% of measured ratios equal to the ratio). Of the measured ratios at 1 in 2 and 1 in 3 that were not equal to the ratio, most were from evaluators using the manual procedure.

There were 4 measured ratios deleted from all analyses (except comparison of evaluators) due to being clearly different from the other 53 measured ratios at the same ratio.

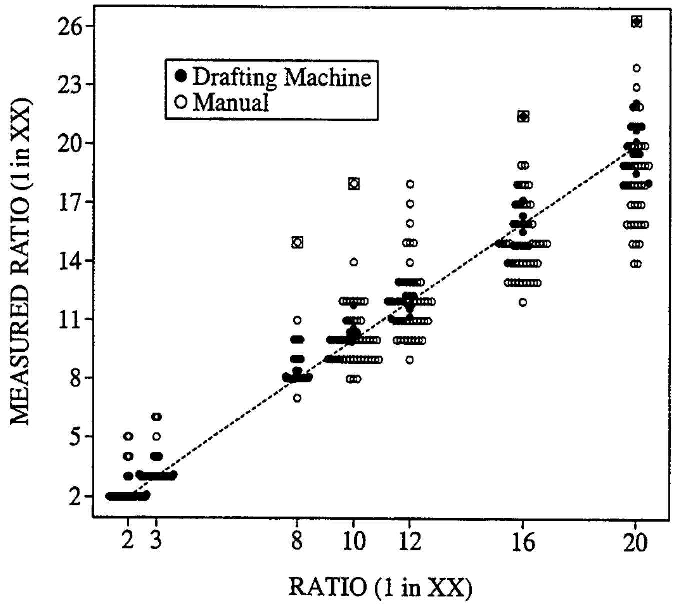


Figure 1 Measured Ratios. Each Symbol Represents An Individual Evaluator and Replication. Ratios Surrounded By A Square Were Not Used To Determine *rL* and *RL*

To determine the significance of differences between the procedures for the mean measured ratio, measured ratios were first averaged across the three replications for each evaluator. These evaluator means were then used in 2-tailed, 2-sample *t*-tests, at each ratio (1 in 8 through 1 in 20), to determine the significance of differences between the machine and manual procedures. If the variance of the two procedures was significantly different, then an approximate *t*-test was used. In addition, *t*-tests were used to determine if any of the mean measured ratios were significantly different from the ratio. Results are shown in Table 2.

Table 2 Comparison of Mean Measured Ratio Between Drafting Machine and Manual Procedure. *p*-values Next to Mean ± Standard Deviation (sd) are From H_o: Mean = Ratio (1 in XX)

Ratio	Machine Procedure		Manual Procedure		Procedure Comparison		
(1 in XX)	Mean ± sd	*p*-value	Mean ± sd	*p*-value	*df*	*t*-value	*p*-value
8	8.20 ± 0.25	0.0829	8.82 ± 0.66	0.0020	14.0	-2.81	0.0139
10	10.10 ± 0.61	0.6916	10.09 ± 1.17	0.8026	16.0	0.01	0.9930
12	12.02 ± 0.60	0.9361	12.06 ± 1.66	0.9059	13.6	-0.08	0.9408
16	15.74 ± 0.93	0.4861	14.88 ± 1.59	0.0411	16.0	1.29	0.2156
20	20.03 ± 1.06	0.9453	17.91 ± 1.76	0.0028	16.0	2.86	0.0114

Results of Table 2 indicate that the procedures differ at 1 in 8 when the mean measured ratio for the manual procedure is significantly greater than the ratio, and at 1 in 20 when the mean measured ratio for the manual procedure is significantly less than the ratio.

There were two variability measures used to compare the drafting machine and manual procedures. The first measure was the pooled variance of the three replications. Results are shown in Table 3. The second measure was the variance of the evaluators (after averaging across the three replications). Results are shown in Table 4. Note the lost degrees of freedom in Table 3 due to the four deleted outliers.

Table 3 Test Results Comparing Procedure for Variance of Three Replications

Ratio (1 in XX)	Pooled sd of Reps		Procedure Comparison		
	Drafting	Manual	*df*	*F*-value	*p*-value
8	0.23	0.93	14,21	16.36	0.0001
10	0.49	1.18	14,21	5.75	0.0016
12	0.49	1.85	14,22	14.10	0.0001
16	0.75	1.48	13,22	3.88	0.0147
20	1.08	2.09	13,22	3.72	0.0179

Table 4 Test Results Comparing Procedure for Variance of Evaluators

Ratio (1 in XX)	sd of Evaluators		Procedure Comparison		
	Drafting	Manual	*df*	*F*-value	*p*-value
8	0.25	0.66	6,10	6.64	0.0309
10	0.61	1.17	6,10	3.77	0.1180
12	0.60	1.66	6,10	7.56	0.0222
16	0.93	1.59	6,10	2.89	0.2071
20	1.06	1.76	6,10	2.77	0.2251

For ratios 1 in 8, through 1 in 20, repeatability limits (*rL*) and reproducibility limits (*RL*) were calculated. Repeatability limit is defined as: approximately 95% of all pairs of replications from the same evaluator and ratio should differ in absolute value by less than the *rL*. Reproducibility limit is defined as: approximately 95% of all pairs of replications from different evaluators and the same ratio should differ in absolute value by less than the *RL*. Table 5 has values for *rL* and *RL*.

Table 5 Repeatability and Reproducibility Limits for Measured Ratio

Ratio (1 in XX)	Procedure	Mean Ratio	*rL*	*RL*	*rL* % of Mean	*RL* % of Mean
8	Machine	8.2	0.6	0.9	8	11
8	Manual	8.8	2.6	2.8	29	31
10	Machine	10.1	1.4	2.0	14	20
10	Manual	10.1	3.3	4.2	32	42
12	Machine	12.0	1.4	2.0	11	17
12	Manual	12.1	5.1	6.2	43	52
16	Machine	15.7	2.1	3.1	13	20
16	Manual	14.9	4.1	5.5	28	37
20	Machine	20.0	3.0	3.8	15	19
20	Manual	17.9	5.8	6.8	32	38

To determine if, in general (i.e., across ratios), some evaluators had a tendency to have greater (or less) measured ratios compared with the other evaluators, paired comparisons were made among the evaluators using ratios 1 in 10 through 1 in 20.

Comparisons were made for each procedure separately since analysis has shown a difference in the procedures.

Within each ratio and procedure, the measured ratios were ranked. Ranks were used to compare the evaluators for the following reasons; (a) variance of the replications increases with increasing ratios making pooling of error across ratios unjustified and (b) the four outliers deleted from other analyses can now be used.

For the manual procedure, the ranks ranged from one to 33 for each ratio (11 evaluators and three replications). For the drafting machine procedure, the ranks ranged from one to 21 (seven evaluators and three replications). Thus, the smallest mean rank an evaluator can have is two (rank of one, two and three for each ratio) and a greatest mean rank of 32 for the manual procedure and 20 for the drafting machine procedure.

Two-tailed t-tests were used for paired comparisons with the error term being the pooled variance of the three replications across all evaluators and the four ratios. Table 6 contains the evaluators and their overall mean rank along with the minimum significant difference (MSD) using a per comparison error level of 0.01. Table 7 shows the measured ratios (1 in XX) for each ratio, evaluator and replication.

Table 6 Mean Rank of Measured Ratios for Each Evaluator (from ratios 1 in 10 through 1 in 20)

Manual Procedure (MSD = 9.6)		Machine Procedure (MSD = 6.7)	
Evaluator	**Mean Rank**	**Evaluator**	**Mean Rank**
M	9.9	P	4.0
E	11.4	A	8.8
H	12.8	B	9.9
F	13.8	O	10.1
G	14.5	N	12.8
J	17.2	C	15.3
K	17.5	Q	16.1
L	18.9		
D	20.2		
I	22.9		
S	28.0		

Table 7 Measured Ratios (1 in XX) for Each Ratio, Evaluator and Replication

Ratio (1 in XX)	Rep	Evaluator																	
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**S**
2	1	2	2.1	2	2	3	3	2	2	5	2	2	4	2	2	2	2	2	2
2	2	2	2	2	2	4	2	2	2	5	2	2	2	2	2	2	2	3	2
2	3	2	2	2	2	4	2	2	2	5	2	2	4	2	2	2	2	2	2
3	1	3	3.1	3.1	3	6	4	3	3	6	3	3	4	3	3	3	3	3	3
3	2	3.1	3	3.1	3	4	4	3	3	6	3	3	3	3	3	3	3	3	3
3	3	3	3	3	4	5	3	3	3	6	3	3	4	3	3	3	3	4	3
8	1	8.2	8.2	8.4	8	10	8	9	8	10	9	10	10	10	8	8	8	8	10
8	2	8	8.1	8.4	9	9	8	8	8	9	11	9	8	8	8	8	8	9	15
8	3	8.1	8.4	8.4	8	8	8	7	9	10	8	8	8	8	8	8	8	9	10
10	1	10.2	10.2	9.9	10	9	9	9	10	11	10	8	9	11	10	10	9	11	12
10	2	10.4	10.4	10.4	10	12	9	10	9	12	11	12	18	9	10	10	9	11	12
10	3	10.6	10.1	11.8	12	8	9	9	9	12	10	8	9	10	9	10	9	10	14
12	1	12.3	11.8	12.3	12	12	11	11	10	11	13	11	10	12	12	11	11	13	18
12	2	11.8	12	11.6	12	10	11	12	10	14	15	10	12	9	13	12	11	13	15
12	3	11.1	11.2	12.3	12	12	11	10	10	13	11	17	16	10	13	12	12	13	15
16	1	14.9	14.9	21.5	14	13	14	14	14	15	17	13	14	15	17	16	16	16	19
16	2	14.9	15.6	16.4	15	13	15	13	13	15	13	16	18	12	17	15	14	16	19
16	3	14.9	14.9	17.2	17	13	13	15	15	14	18	14	18	13	16	15	14	18	17
20	1	18.6	19.6	26.4	19	16	18	18	17	20	16	23	17	15	21	21	18	22	20
20	2	18.1	20.2	22.2	19	19	18	22	17	20	15	19	17	14	19	20	18	22	20
20	3	19.6	20.8	19.6	16	14	19	16	24	18	15	20	18	16	21	21	19	19	16

Part 2 - GLS of Photographs

Each evaluator was asked to measure the largest slope they could find on each of ten photos. For half of the photos, an undistorted area outside the windscreen was provided for reference. There were two main questions of interest. First, is the variability of the evaluators for the measured ratios different between the drafting machine and manual procedures? Second, is the variability of the evaluators for the measured ratios different between the referenced and non-referenced photos?

Table 8 contains comparisons of procedure for each reference, using the pooled variance of evaluators across the five photos. There is also a comparison of procedure where the variance was pooled across reference. Table 9 contains comparisons of reference for each procedure, using the pooled variance of evaluators across the five photos. There is also a comparison of reference where the variance was pooled across procedure. Table 10 contains reproducibility limits for each combination of procedure and reference. Reproducibility limit is defined as: approximately 95% of all pairs of replications from different evaluators and the same photo should differ in absolute value by less than the *RL*.

Table 8 Test Results Comparing Procedure for Variance of Evaluators

Referenced	Pooled sd of Evaluators		Procedure Comparison		
	Machine	Manual	*df*	*F*-value	*p*-value
No	3.02	4.12	29,50	1.87	0.0734
Yes	3.94	4.32	30,49	1.20	0.5939
Pooled Across	3.51	4.22	59,99	1.44	0.1271

Table 9 Test Results Comparing Reference for Variance of Evaluators

Procedure	Pooled sd of Evaluators		Reference Comparison		
	No Reference	Referenced	*df*	*F*-value	*p*-value
Drafting Machine	3.02	3.94	29,30	1.70	0.1557
Manual	4.12	4.32	50,49	1.10	0.7454
Pooled Across	3.76	4.18	79,79	1.24	0.3458

Table 10 Reproducibility Limits for Measured Ratio

Procedure	Referenced	Mean Ratio	*RL*	*RL* % of Mean
Machine	no	9.4	8.4	89
Machine	yes	10.4	10.9	105
Manual	no	10.8	11.4	106
Manual	yes	10.2	12.0	117

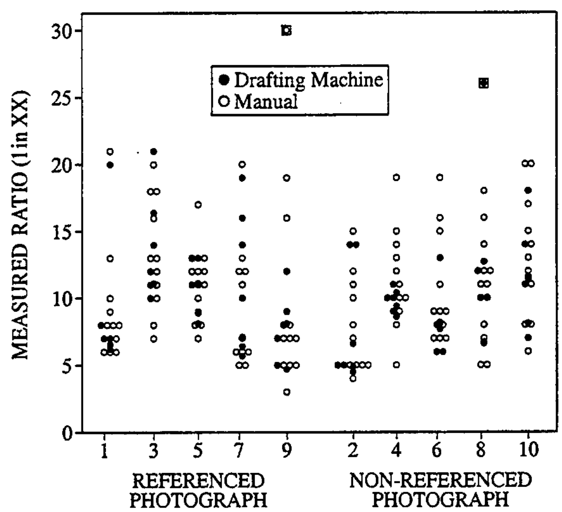


Figure 2 Measured Ratios. Each Symbol Represents An Individual Evaluator. Ratios Surrounded By A Square Were Not Used To Determine *RL*

Table 11 Measure Ratios (1 in XX) for Each Photo and Evaluator

Photo	Evaluator																	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	S
1	6.2	6.6	6.5	6	7	21	8	9	6	6	13	8	8	20	7	8	7	10
2	4.9	6.6	4.5	5	8	12	5	4	7	10	15	5	11	14	5	14	5	5
3	11.1	16.4	14	10	11	16	7	8	12	18	18	13	13	11	21	12	10	20
4	10.4	8.6	9.4	8	10	15	5	9	14	10	11	12	13	11	9	10	10	19
5	11.1	8.9	8.1	8	11	12	7	8	11	12	10	12	13	13	13	11	9	17
6	8.2	7.7	8.1	7	9	8	9	7	19	7	11	16	9	8	6	13	6	15
7	5.7	7.1	6.4	6	6	12	6	5	7	11	13	12	20	16	19	14	10	5
8	6.7	12.7	6.6	8	5	11	5	7	14	12	12	11	16	26	12	10	10	18
9	12	8.1	4.7	5	7	5	3	5	7	19	7	30	16	7	8	9	5	8
10	11.4	11.6	8.1	8	11	13	6	12	14	8	20	17	15	18	14	11	7	20

After completion of the data collection and analysis of Part 2, 10 in-house evaluators not involved in the measured ratio data collection were shown each of the 10 photos. These evaluators were asked to rank the distortion quality of the photos from A (little or no distortion) to F (major distortion). These rankings were rated (A = 6, B = 5, C = 4, D = 3, E = 2, F = 1) so that a smaller rating implies a greater distortion. The median rating among evaluators was determined. These medians were correlated with the median measured ratio from data in Part 2. Results are shown in Figure 1. A significant positive correlation would indicate that if the evaluators rated a photo as having more distortion than another, that photo would also have the greatest slope.

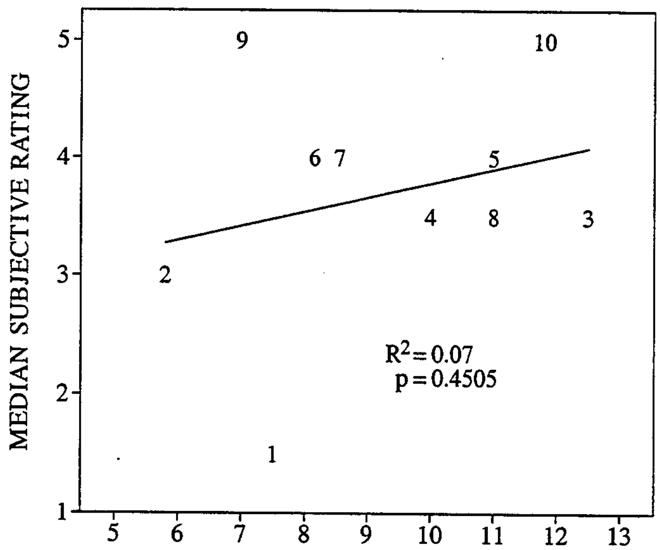


Figure 3 Correlation Between the Median Subjective Rating and Median Measured Ratio. Values in the Figure Are the Photo Numbers

8. RESEARCH REPORT SUMMARY

Precision for Part 1, GLS of Gaussian Curves

The statistical summary for repeatability limit (*rL*) and reproducibility limit (*RL*) derived from Gaussian curves is shown in Table 12. Statistical analyses (in accordance with ASTM Standard Practices E 691 and E 177) revealed that in Part 1 of the ILS study, the *rL* was approximately 33% of the mean for the manual procedure and approximately 12% of the mean for the drafting machine procedure across GLS. The *RL* was approximately 40% of the mean for the manual procedure and approximately 17% of the mean for the

drafting machine procedure across GLS. Results indicate that using a drafting machine instead of a manual procedure reduces both within and between evaluators' measurement variability by over 50%.

Table 12 *rL* and *RL* for Gaussian Curve GLS Measurements

PROCEDURE	*rL* % of MEAN	*RL* % of MEAN
Drafting Machine	12	17
Manual	33	40

Precision for Part 2, GLS of Photographs

The evaluators were asked to measure the largest slope angle they could find on each of 10 photos. For half of the photographs, an undistorted area outside the windscreen was provided as a reference for measurements. The other half of the photographs had no undistorted reference area. For these photographs, the lowest distortion areas were used for reference.

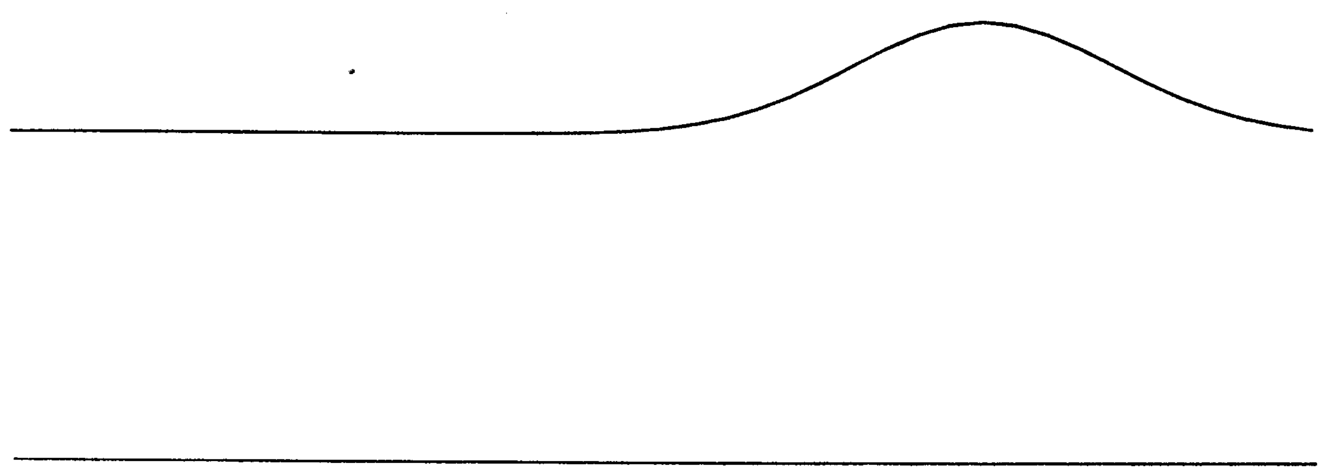
Table 10 contains both the mean ratios and the *RL* for each combination of procedure and reference. Differences among pairs of measured distortions can vary by as much as 100%. There were no significant differences between the procedures or reference.

In general, there are other sources of variability in the measurement of distortion including, but not limited to: distances, camera lens distortion, film and photographic processing. If not controlled for, these variables may also contribute to increased distortion measurement variability.

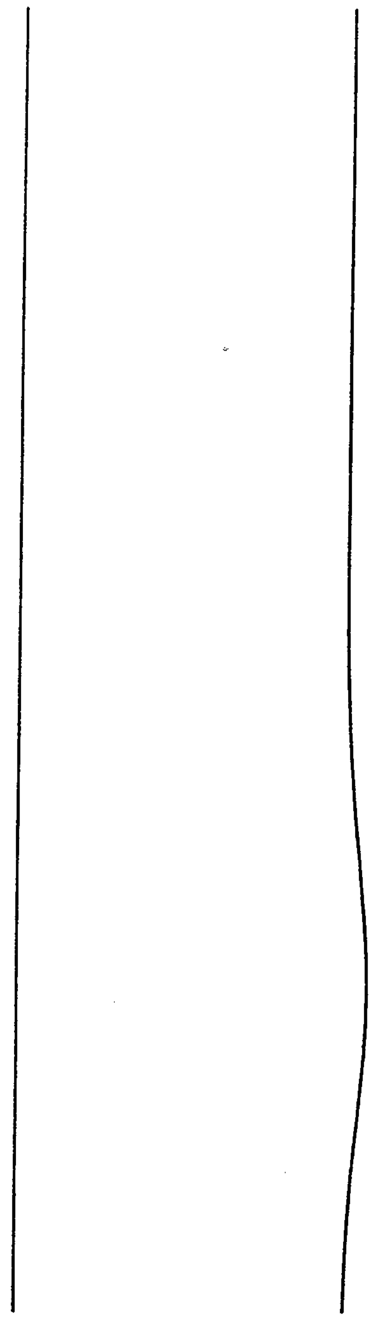
Bias: The procedure in this test method has no bias since GLS is defined only in terms of the test method.

APPENDIX A(1). The Computer-Generated Gaussian Curves used for practice.

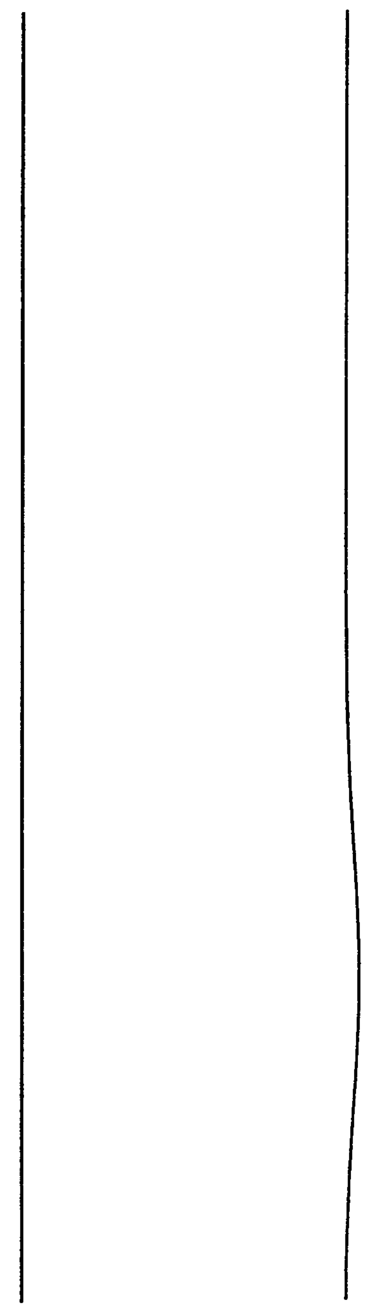
sample

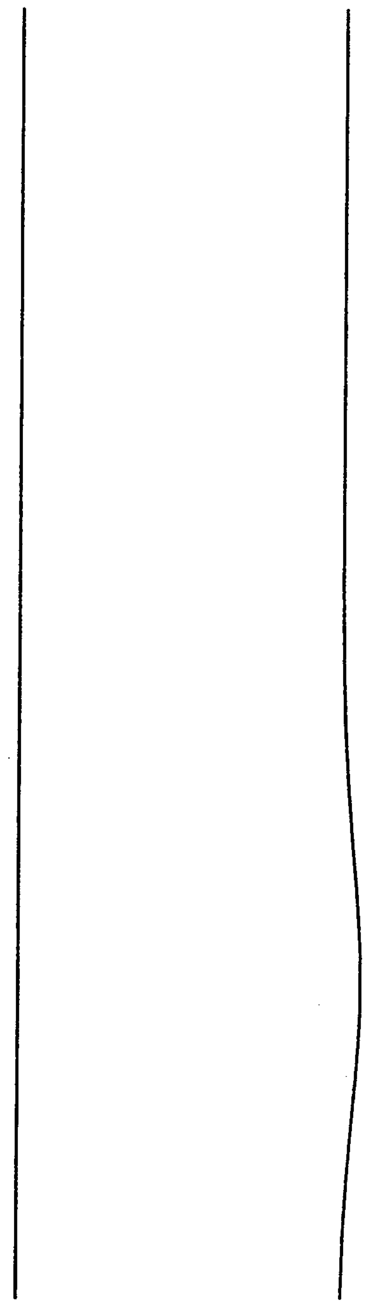


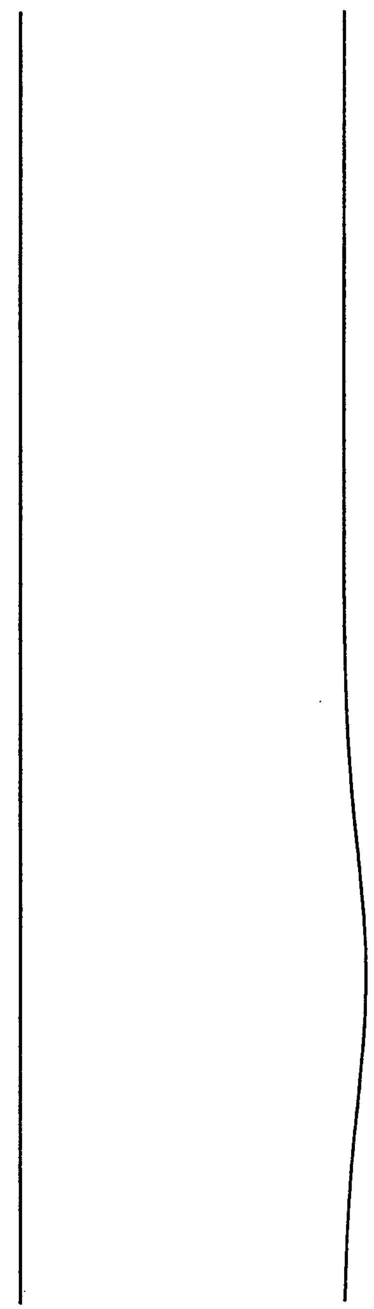
ref

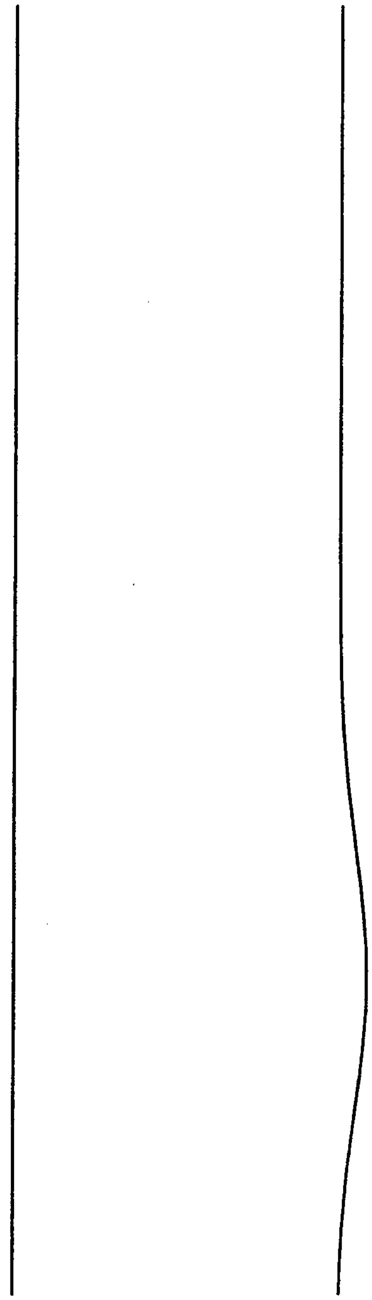


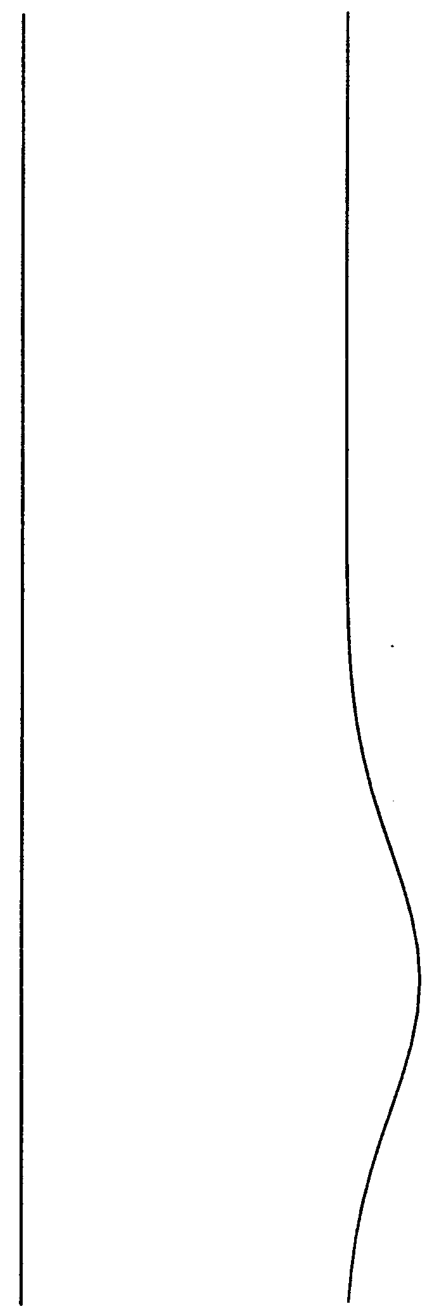
APPENDIX A(2). The Computer-Generated Gaussian Curves ordered from lowest to highest slope.

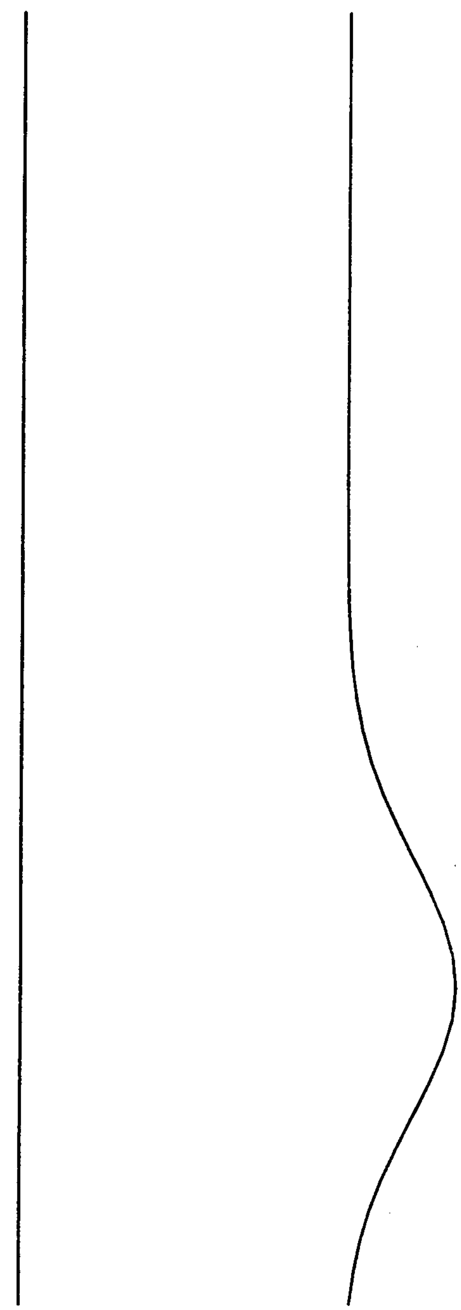












APPENDIX A(3). A transparent grid overlay was provided as an aid in GLS measurements performed without the use of a drafting machine. This is a copy of the transparent grid.

APPENDIX A(4). The experimental trials were presented in randomized order. This is the key that relates the actual curve to any given trial.

Gaussian Curve Presentation Order Grid Line Slope Interlaboratory Study 12/98

Sample #	Lab A	GLS	Lab B	GLS	Lab C	GLS	Lab D	GLS	Lab E	GLS	Lab F	GLS
1	1	1:2	16	1:16	17	1:16	13	1:12	2	1:2	21	1:20
2	19	1:20	15	1:12	20	1:20	4	1:3	11	1:10	11	1:10
3	6	1:3	9	1:8	6	1:3	8	1:8	8	1:8	3	1:2
4	13	1:12	3	1:2	8	1:8	20	1:20	13	1:12	14	1:12
5	8	1:8	21	1:20	2	1:2	11	1:10	18	1:16	4	1:3
6	12	1:10	12	1:10	11	1:10	16	1:16	5	1:3	7	1:8
7	16	1:16	6	1:3	13	1:12	1	1:2	20	1:20	17	1:16
8	5	1:3	11	1:10	21	1:20	3	1:2	10	1:10	16	1:16
9	3	1:2	14	1:12	14	1:12	6	1:3	7	1:8	13	1:12
10	18	1:16	19	1:20	5	1:3	7	1:8	4	1:3	19	1:20
11	15	1:12	17	1:16	7	1:8	18	1:16	15	1:12	6	1:3
12	11	1:10	1	1:2	10	1:10	12	1:10	3	1:2	12	1:10
13	21	1:20	4	1:3	18	1:16	15	1:12	17	1:16	9	1:8
14	7	1:8	7	1:8	1	1:2	21	1:20	19	1:20	1	1:2
15	20	1:20	20	1:20	3	1:2	17	1:16	9	1:8	15	1:12
16	17	1:16	2	1:2	4	1:3	14	1:12	16	1:16	20	1:20
17	4	1:3	13	1:12	16	1:16	2	1:2	21	1:20	5	1:3
18	10	1:10	8	1:8	15	1:12	10	1:10	1	1:2	2	1:2
19	9	1:8	5	1:3	12	1:10	9	1:8	12	1:10	10	1:10
20	2	1:2	10	1:10	9	1:8	5	1:3	6	1:3	8	1:8
21	14	1:12	18	1:16	19	1:20	19	1:20	14	1:12	18	1:16

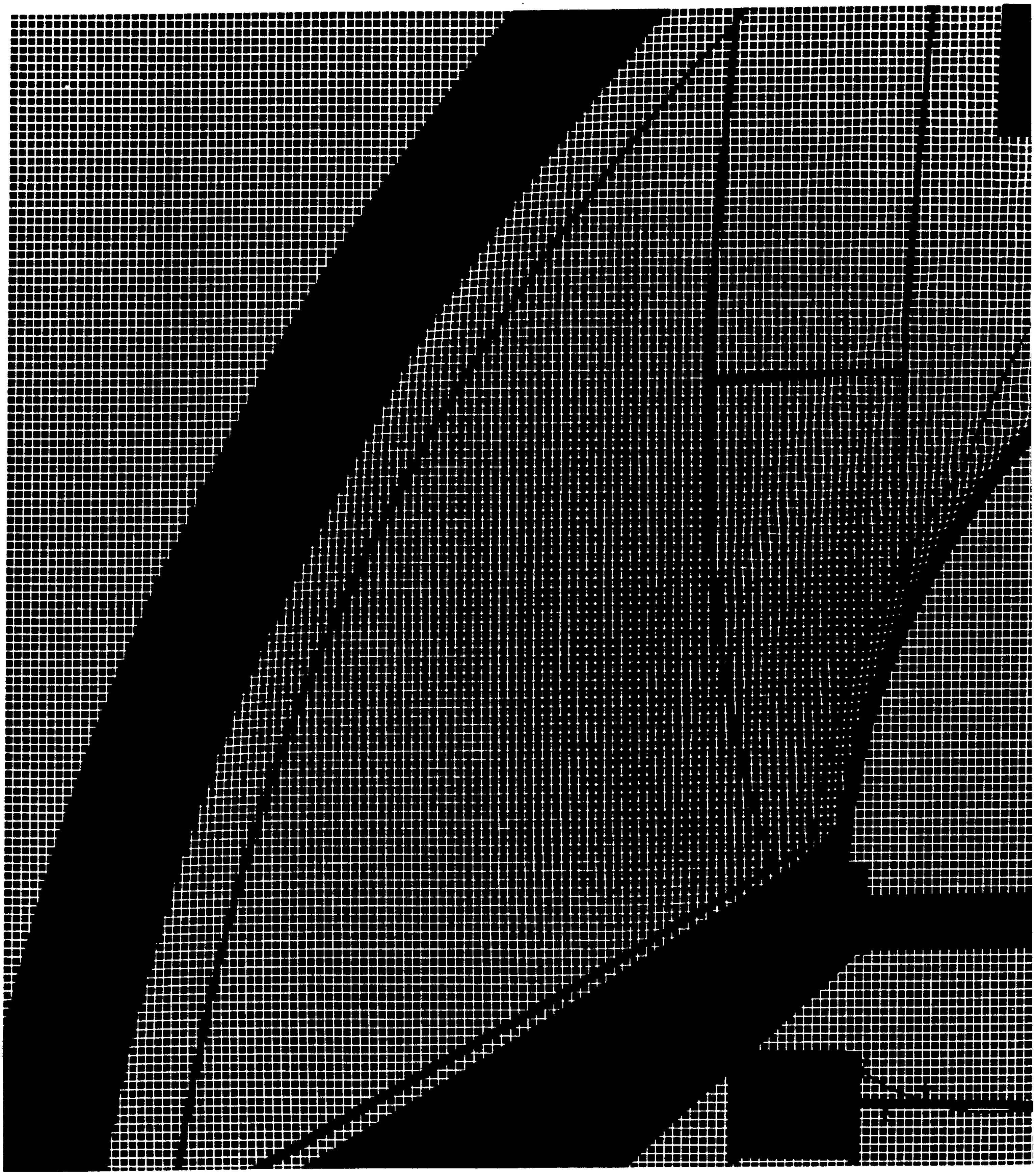
Sample #	Lab G	GLS	Lab H	GLS	Lab I	GLS	Lab J	GLS	Lab K	GLS	Lab L	GLS
1	11	1:10	5	1:3	21	1:20	7	1:8	14	1:12	5	1:3
2	19	1:20	10	1:10	5	1:3	18	1:16	10	1:10	20	1:20
3	5	1:3	3	1:2	18	1:16	19	1:20	20	1:20	10	1:10
4	2	1:2	8	1:8	12	1:10	14	1:12	18	1:16	14	1:12
5	8	1:8	18	1:16	13	1:12	12	1:10	1	1:2	1	1:2
6	16	1:16	14	1:12	1	1:2	1	1:2	7	1:8	18	1:16
7	13	1:12	19	1:20	9	1:8	4	1:3	5	1:3	7	1:8
8	15	1:12	17	1:16	6	1:3	15	1:12	11	1:10	3	1:2
9	18	1:16	2	1:2	14	1:12	10	1:10	3	1:2	4	1:3
10	20	1:20	6	1:3	7	1:8	9	1:8	13	1:12	8	1:8
11	6	1:3	21	1:20	16	1:16	20	1:20	19	1:20	17	1:16
12	10	1:10	13	1:12	3	1:2	2	1:2	4	1:3	15	1:12
13	9	1:8	11	1:10	10	1:10	5	1:3	8	1:8	11	1:10
14	1	1:2	7	1:8	20	1:20	17	1:16	17	1:16	21	1:20
15	7	1:8	1	1:2	8	1:8	11	1:10	16	1:16	19	1:20
16	4	1:3	9	1:8	17	1:16	16	1:16	15	1:12	16	1:16
17	3	1:2	15	1:12	4	1:3	8	1:8	9	1:8	6	1:3
18	14	1:12	12	1:10	11	1:10	13	1:12	12	1:10	9	1:8
19	17	1:16	4	1:3	2	1:2	3	1:2	21	1:20	2	1:2
20	12	1:10	20	1:20	19	1:20	6	1:3	2	1:2	13	1:12
21	21	1:20	16	1:16	15	1:12	21	1:20	6	1:3	12	1:10

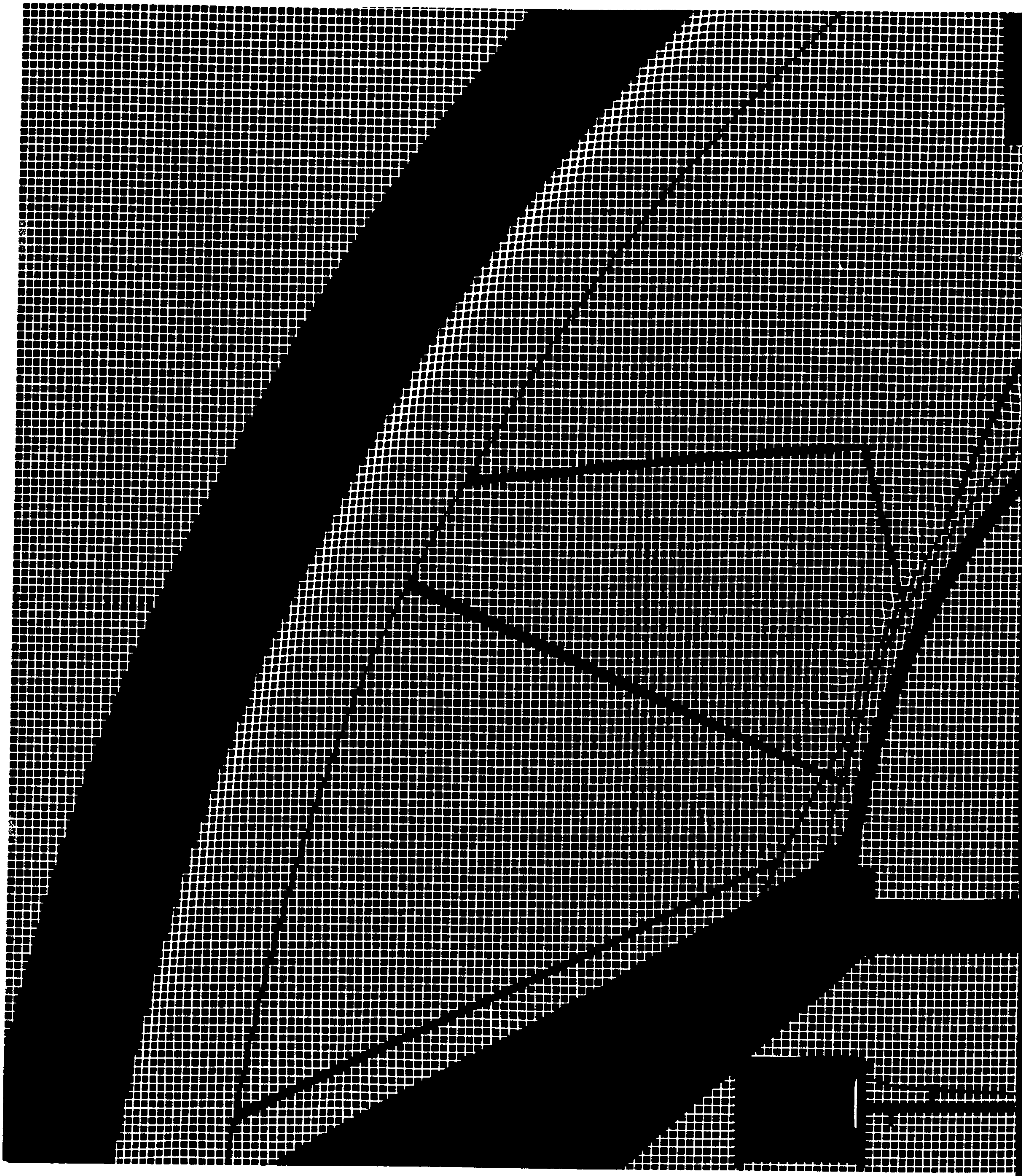
Sample #	Lab M	GLS	Lab N	GLS	Lab O	GLS	Lab P	GLS	Lab Q	GLS	Lab R	GLS
1	7	1:8	12	1:10	3	1:2	8	1:8	7	1:8	4	1:3
2	18	1:16	21	1:20	19	1:20	17	1:16	17	1:16	16	1:16
3	13	1:12	5	1:3	14	1:12	21	1:20	20	1:20	2	1:2
4	2	1:2	13	1:12	12	1:10	15	1:12	12	1:10	8	1:8
5	11	1:10	7	1:8	6	1:3	10	1:10	6	1:3	21	1:20
6	20	1:20	1	1:2	7	1:8	1	1:2	14	1:12	13	1:12
7	4	1:3	17	1:16	18	1:16	6	1:3	3	1:2	12	1:10
8	14	1:12	6	1:3	4	1:3	4	1:3	21	1:20	20	1:20
9	3	1:2	15	1:12	17	1:16	2	1:2	10	1:10	6	1:3
10	21	1:20	2	1:2	9	1:8	16	1:16	2	1:2	14	1:12
11	9	1:8	9	1:8	11	1:10	14	1:12	16	1:16	17	1:16
12	5	1:3	16	1:16	20	1:20	12	1:10	13	1:12	3	1:2
13	12	1:10	19	1:20	15	1:12	7	1:8	9	1:8	11	1:10
14	16	1:16	11	1:10	1	1:2	19	1:20	4	1:3	9	1:8
15	1	1:2	20	1:20	16	1:16	11	1:10	5	1:3	10	1:10
16	19	1:20	8	1:8	8	1:8	5	1:3	18	1:16	7	1:8
17	17	1:16	4	1:3	10	1:10	18	1:16	8	1:8	18	1:16
18	15	1:12	18	1:16	2	1:2	9	1:8	11	1:10	1	1:2
19	6	1:3	10	1:10	5	1:3	3	1:2	19	1:20	5	1:3
20	10	1:10	14	1:12	21	1:20	20	1:20	15	1:12	19	1:20
21	8	1:8	3	1:2	13	1:12	13	1:12	1	1:2	15	1:12

Sample #	Lab S	GLS
1	8	1:8
2	10	1:10
3	4	1:3
4	20	1:20
5	18	1:16
6	2	1:2
7	14	1:12
8	15	1:12
9	6	1:3
10	16	1:16
11	19	1:20
12	1	1:2
13	7	1:8
14	12	1:10
15	3	1:2
16	5	1:3
17	21	1:20
18	11	1:10
19	13	1:12
20	17	1:16
21	9	1:8

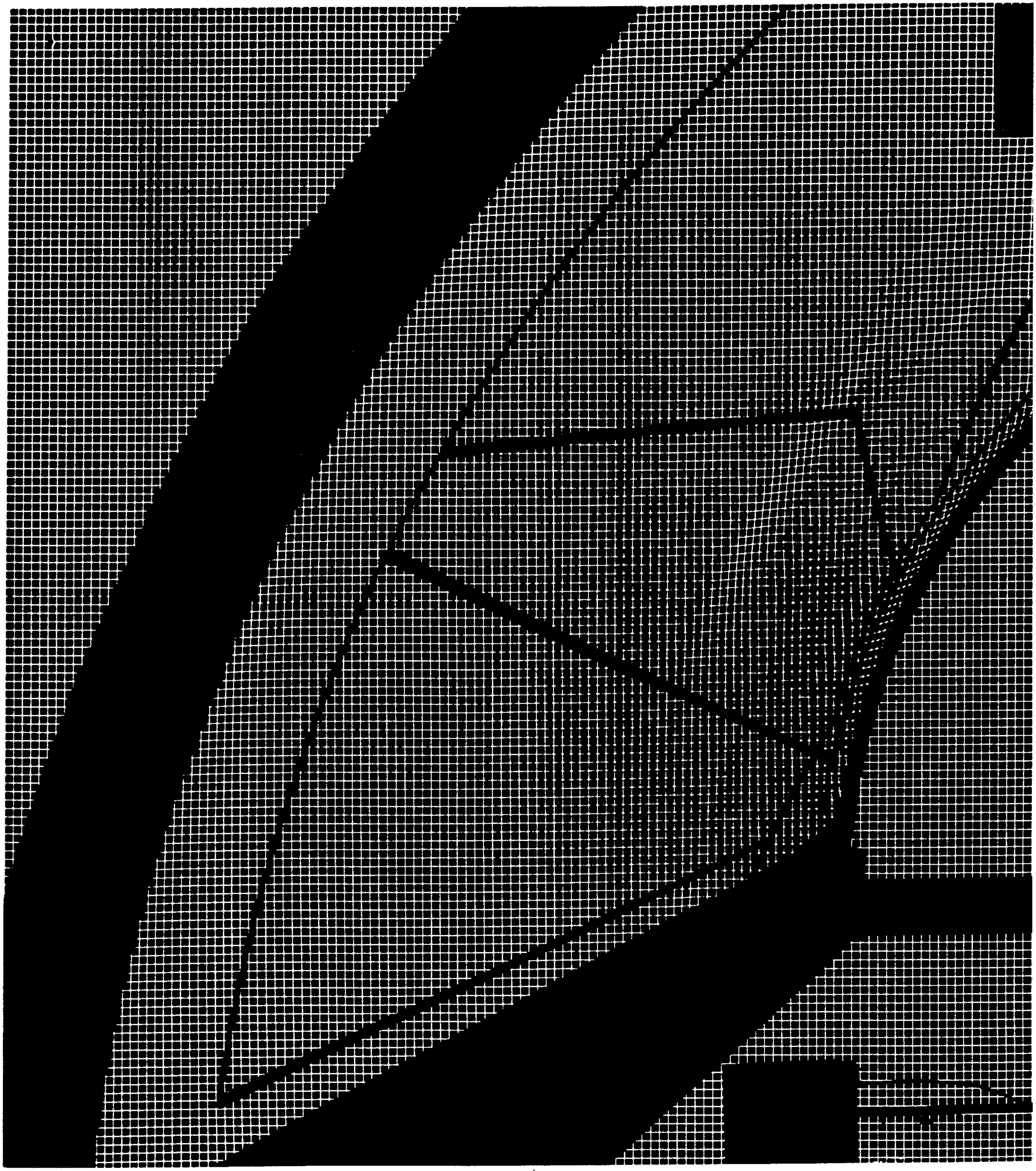
GLS Ratio 1:2 = Gaussian Curves 1,2,3
GLS Ratio 1:3 = Gaussian Curves 4,5,6
GLS Ratio 1:8 = Gaussian Curves 7,8,9
GLS Ratio 1:10 = Gaussian Curves 10,11,12
GLS Ratio 1:12 = Gaussian Curves 13,14,15
GLS Ratio 1:16 = Gaussian Curves 16,17,18
GLS Ratio 1:20 = Gaussian Curves 19,20,21

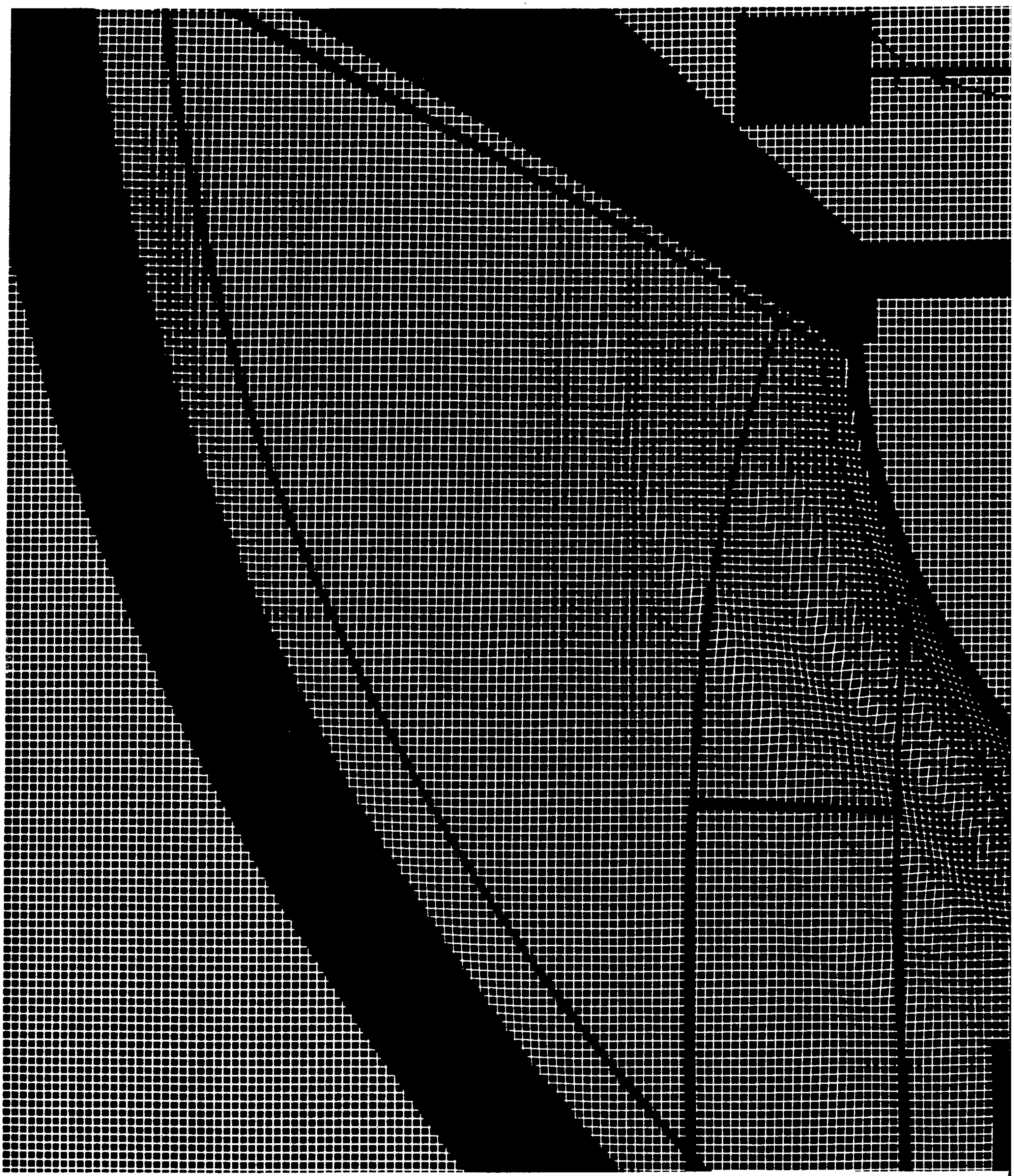
APPENDIX B(1). Photographs of GLS (with Reference Area).



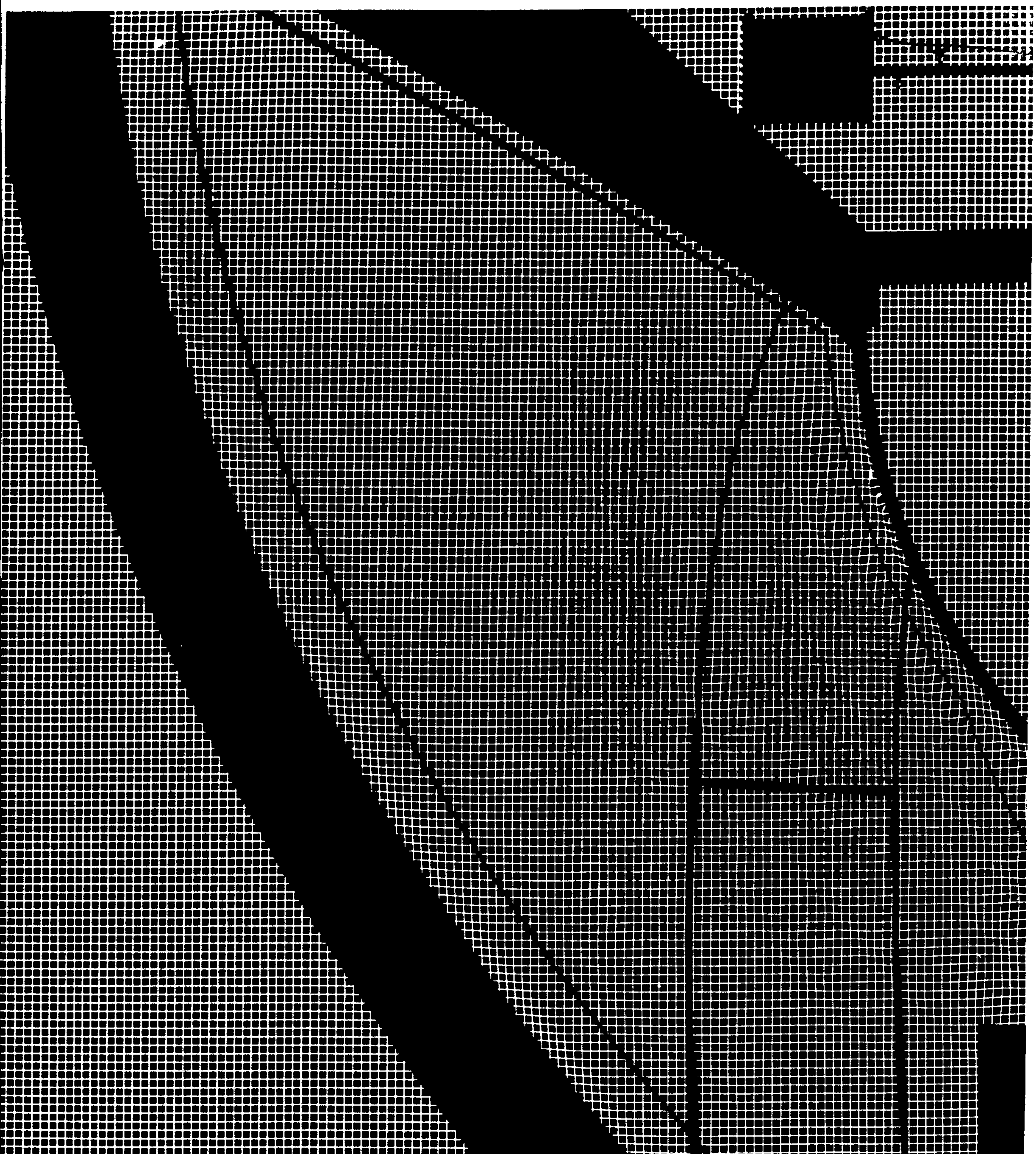


33

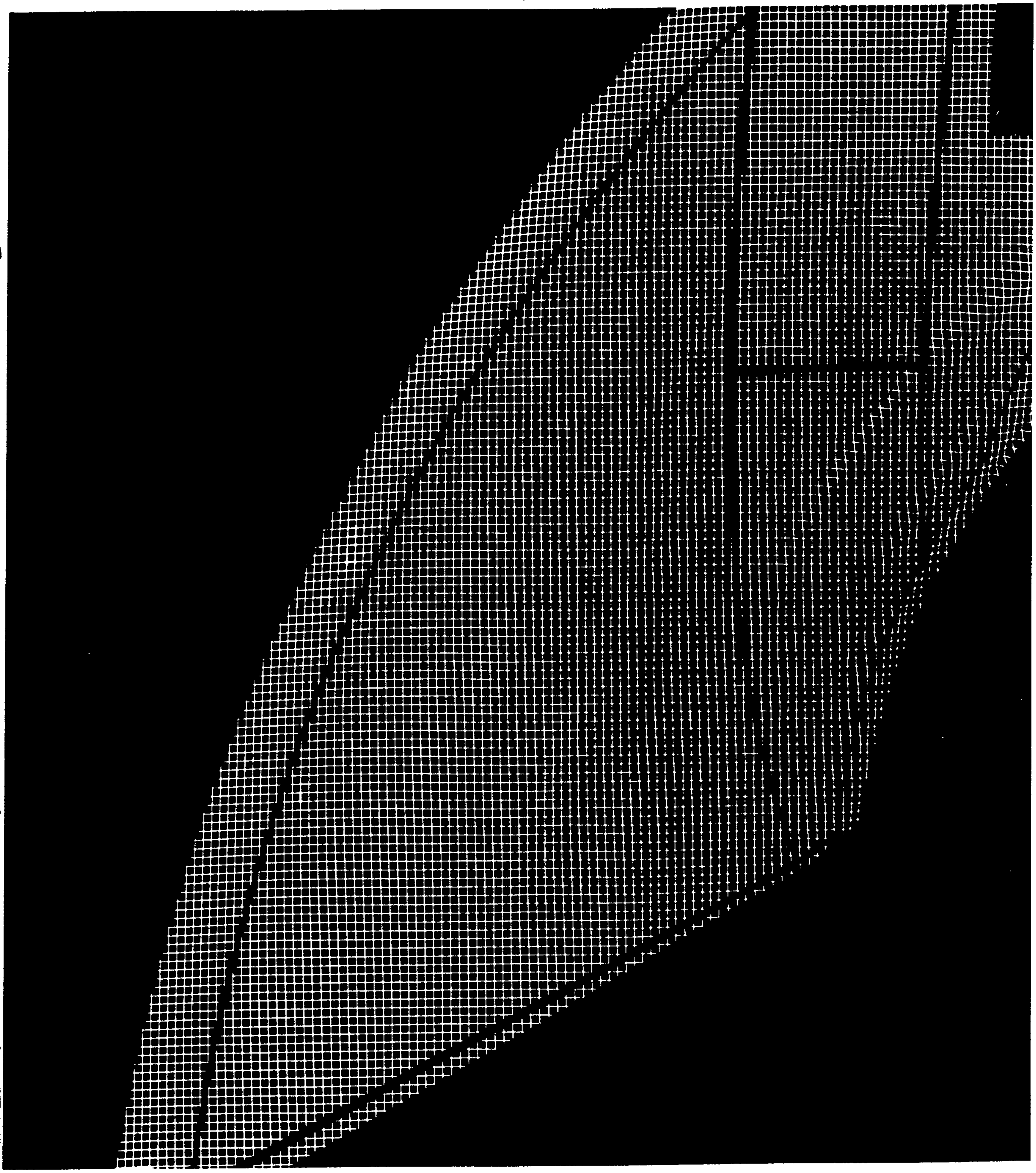


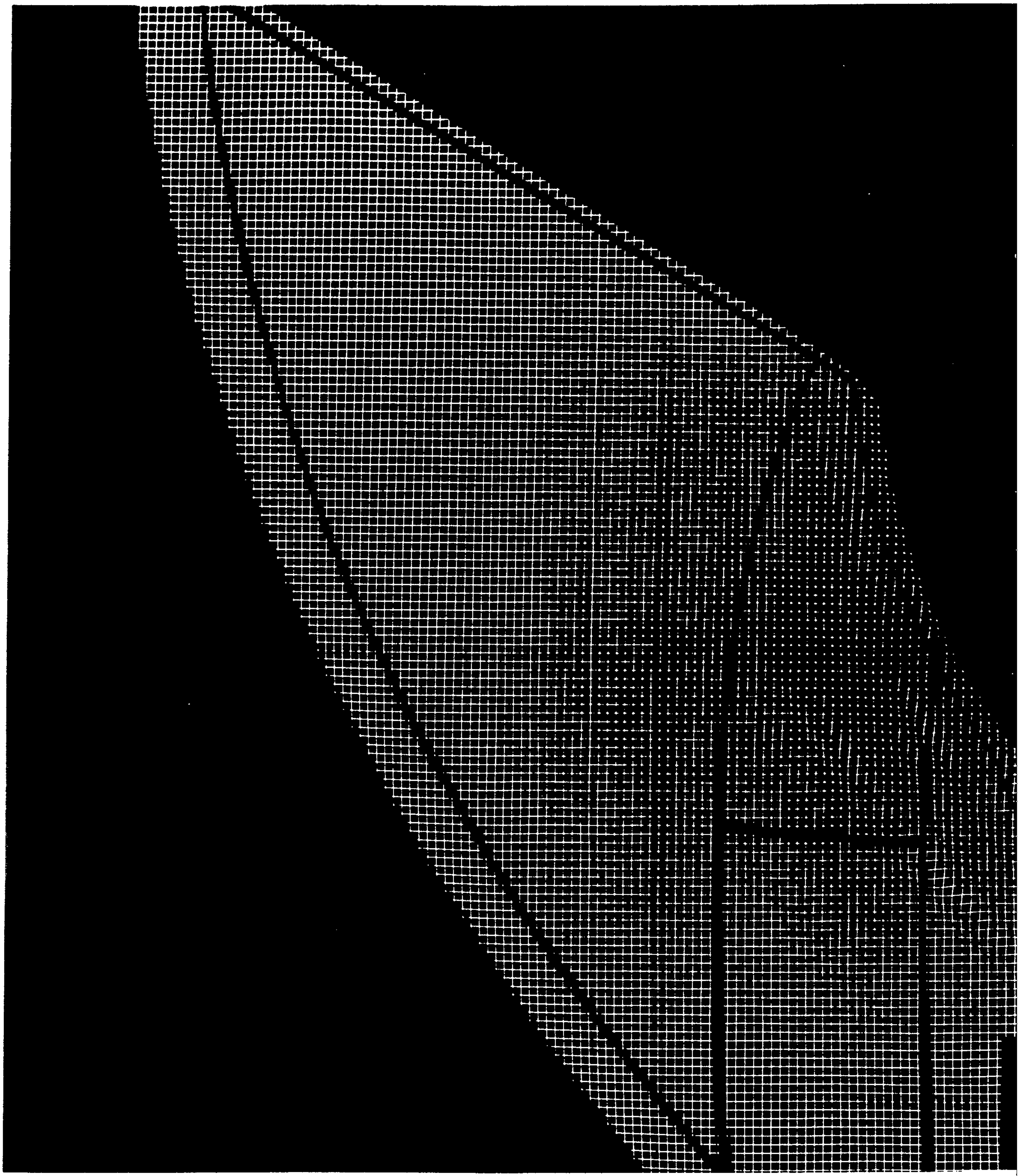


76

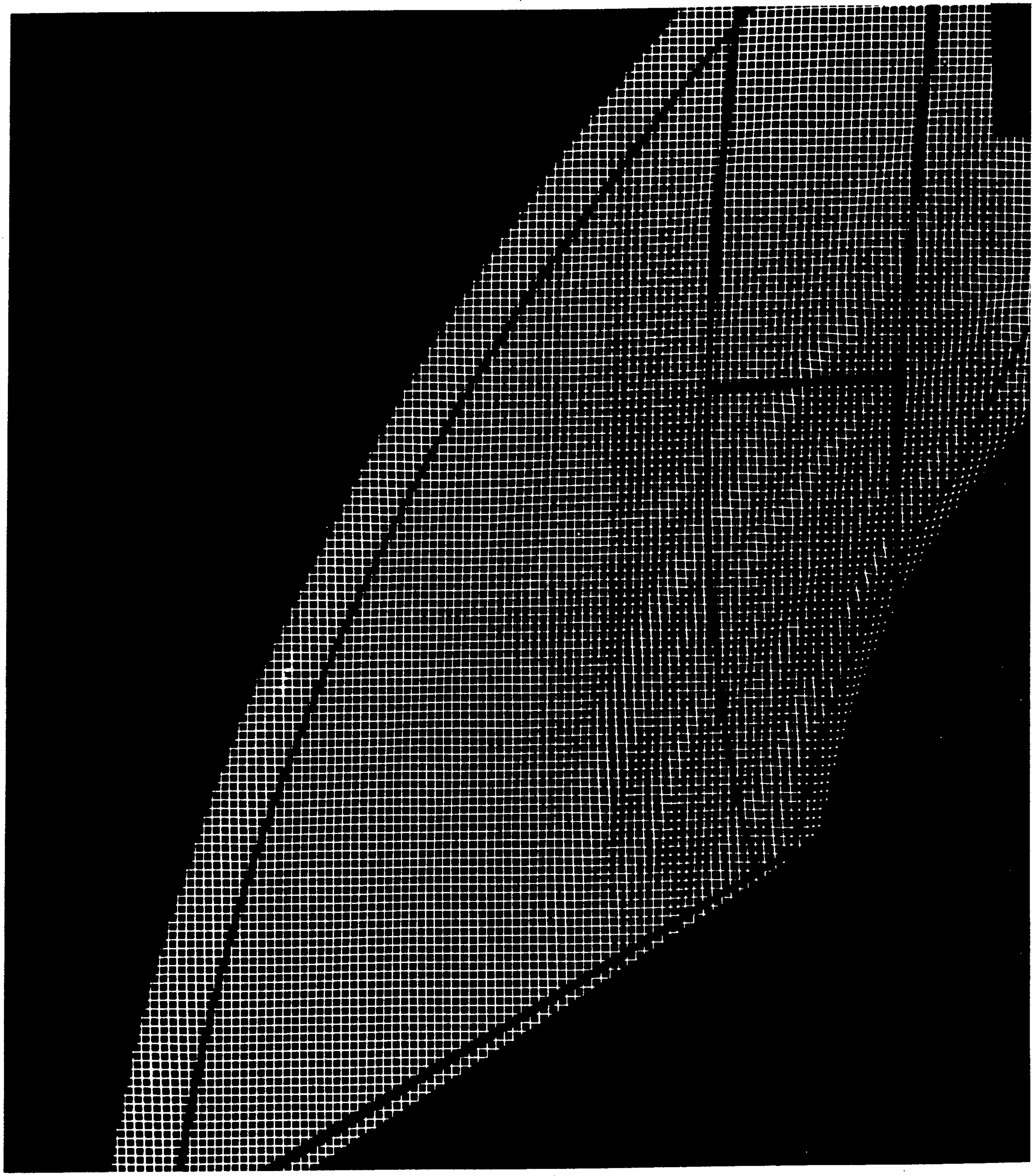


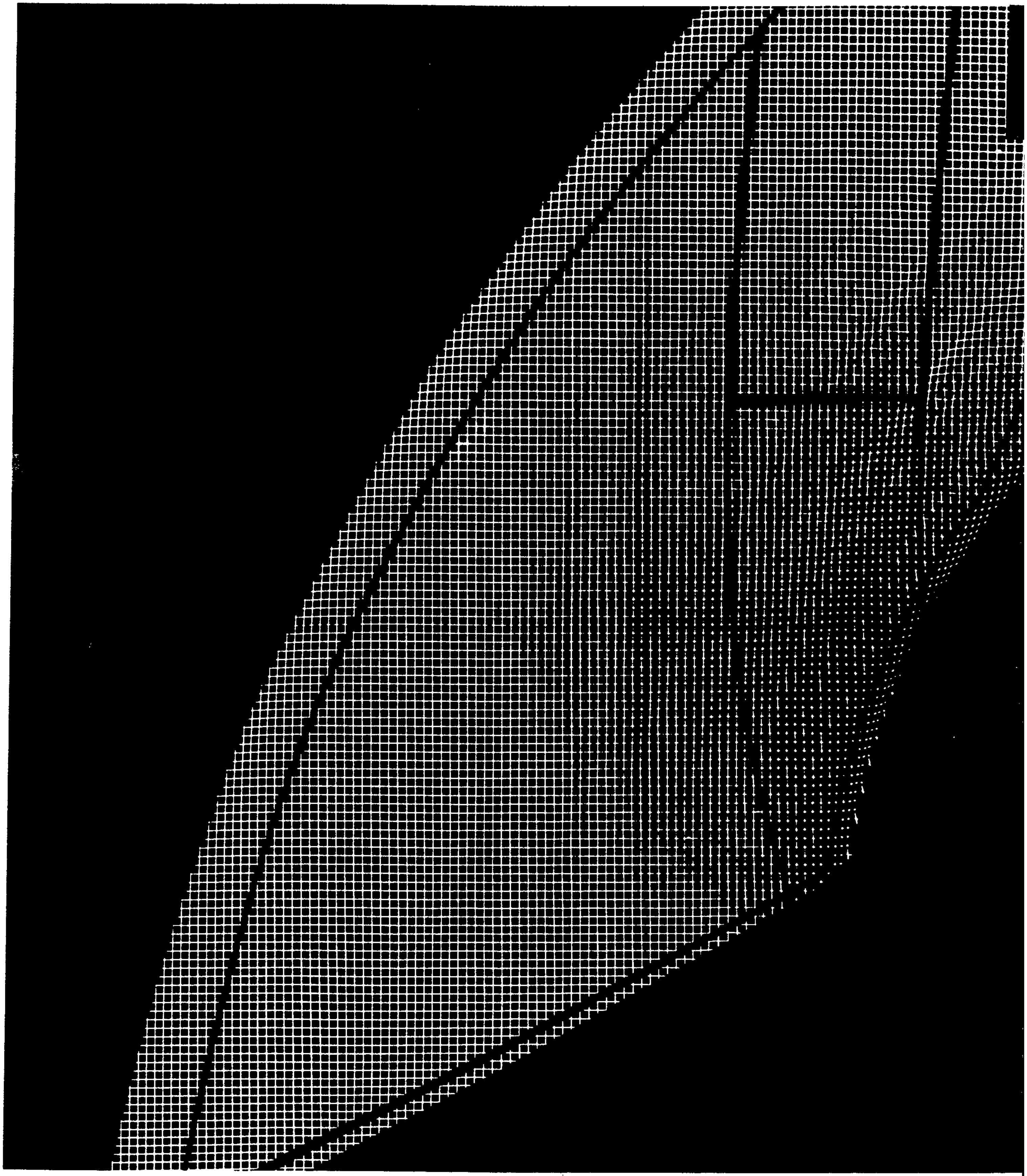
APPENDIX B(2). Photographs of GLS (without Reference Area).

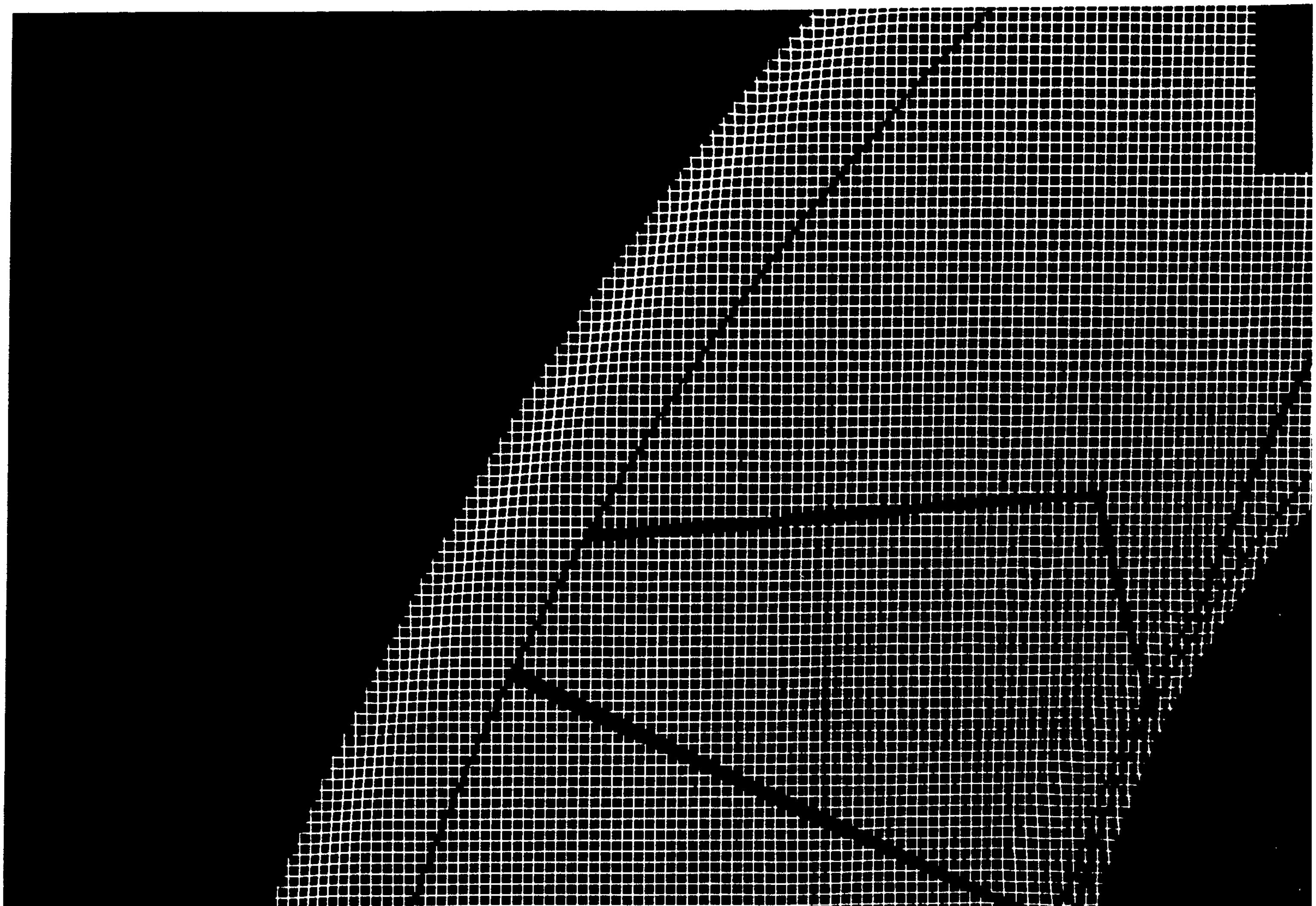




37







APPENDIX B(3). The experimental trials were presented in randomized order. This is the key that relates the specific photograph to any given trial.

Photo Presentation Order for Grid Line Slope Interlaboratory Study 12/10/98

Sample #	Lab A	Lab B	Lab C	Lab D	Lab E	Lab F	Lab G	Lab H	Lab I	Lab J
22	4	9	1	2	5	6	7	8	3	10
23	10	8	6	3	9	4	2	5	7	1
24	8	7	3	1	10	5	6	4	9	2
25	7	3	10	4	2	8	9	1	6	5
26	9	2	8	10	1	3	4	7	5	6
27	2	6	9	5	8	1	3	10	4	7
28	6	4	5	9	7	2	1	3	10	8
29	1	10	2	7	3	9	5	6	8	4
30	5	1	7	6	4	10	8	9	2	3
31	3	5	4	8	6	7	10	2	1	9

Sample #	Lab K	Lab L	Lab M	Lab N	Lab O	Lab P	Lab Q	Lab R	Lab S
22	2	3	9	4	6	7	8	10	1
23	7	4	6	1	10	5	2	3	8
24	10	5	1	6	7	9	4	8	2
25	5	8	3	9	1	2	7	4	10
26	8	10	4	3	2	6	5	9	7
27	3	2	8	10	5	1	9	7	6
28	9	6	10	2	8	4	1	5	3
29	4	7	5	8	3	10	6	1	9
30	1	9	2	7	4	3	10	6	5
31	6	1	7	5	9	8	3	2	4

APPENDIX C. Data Report forms 1 through 19. Note: the experimental trials were presented in randomized order. For the actual trial presentation orders, see Appendices A(4) and B(3).

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: A

Date: 7-21-99

Organization:

Brief description of measurement equip. and technique used:

DIGITAL DRAFTING MACHINE

Sample #	GLS	deg		Sample #	GLS	H or V	deg	
1	1: 2.0	26°20'	1:2	22 4	1: 10.4	H	5°30'	1:9
2	1: 18.6	3°05'	1:20	23 10	1: 11.4	H	5°00'	1:15
3	1: 3.0	18°25'	1:3	24 8	1: 6.7	H	8°30'	1:17
4	1: 12.3	4°40'	1:12	25 7	1: 5.7	H	9°55'	1:12
5	1: 8.2	6°55'	1:8	26 9	1: 12.0	H	4°45'	1:14
6	1: 10.2	5°35'	1:10	27 2	1: 4.9	H	11°35'	1:7
7	1: 14.9	3°50'	1:16	28 6	1: 8.2	H	6°55'	1:9
8	1: 3.1	18°10'	1:3	29 1	1: 6.2	H	9°10'	1:7
9	1: 2.0	26°35'	1:2	30 5	1: 11.1	H	5°10'	1:12
10	1: 14.9	3°50'	1:16	31 3	1: 11.1	H	5°10'	1:12
11	1: 11.8	4°50'	1:12					
12	1: 10.4	5°30'	1:10	Practice	GLS			
13	1: 18.1	3°10'	1:20	1	1: 2	26°25'		
14	1: 5.0	7°10'	1:8	2	1: 2	26°25'		
15	1: 19.6	2°55'	1:20	3	1: 11	5° 0'		
16	1: 14.9	3°50'	1:16	4	1: 10	5° 50'		
17	1: 3.0	18°30'	1:3	5	1: 10	5° 40'		
18	1: 10.6	5°25'	1:10	6	1:			
19	1: 8.1	7°05'	1:8	7	1:			
20	1: 2.0	26°40'	1:2	8	1:			
21	1: 11.1	5°10'	1:12	9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: B

Date: 7-21-99

Organization:

Brief description of measurement equip. and technique used:

DIGITAL DRAFTING MACHINE

Sample #	GLS	Degrees		Sample #		GLS	H or V	Degrees		
1	1: 14.3	3°50'	1:16	22	5	1: 8.1	H	~~4°50'~~	7° ~~8°10'~~	1:14
2	1: 11.8	4°50'	1:12	23	8	1: 12.7	H	4°30'	1:17	
3	1: 8.2	6°55'	1:8	24	7	1: 7.1	H	8°	1:12	
4	1: 2.1	26°	1:2	25	3	1: 16.4	H	3°30'	1:12	
5	1: 19.6	2°55'	1:20	26	2	1: 6.6	H	8°35'	1:7	
6	1: 10.2	5°35'	1:10	27	6	1: 7.7	H	7°25'	1:9	
7	1: 3.1	18°10'	1:3	28	4	1: 8.6	H	6°40'	1:9	
8	1: 10.[illegible]	5°30'	1:10	29	10	1: 11.6	H	4°55'	1:15	
9	1: 12.0	4°45'	1:12	30	1	1: 6.6	H	8°35'	1:7	
10	1: 20.2	2°50'	1:20	31	6	1: 8.9	H	~~3~~6°25'	1:12	
11	1: 15.6	3°40'	1:16							
12	1: 2.0	26°10'	1:2	Practice		GLS				
13	1: 3.0	18°25'	1:3	1		1:	26°40'			
14	1: 8.1	7°05'	1:8	2		1:	26°40'			
15	1: 20.8	2°45'	1:20	3		1:	5°35'			
16	1: 2.0	26°50'	1:2	4		1:	5°5'			
17	1: 11.2	5°05'	1:12	5		1:	5°30'			
18	1: 8.4	6°50'	1:8	6		1:				
19	1: 3.0	18°15'	1:3	7		1:				
20	1: 10.1	5°40'	1:10	8		1:				
21	1: 14.9	3°50'	1:16	9		1:				
				10		1:				

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: | Data Set: C

Date: 7-21-99

Organization:

Brief description of measurement equip. and technique used:

DIGITAL DRAFTING BOARD

Sample #	GLS	DEG.	
1	1: 21.5	2.40	1:16
2	1: 24.4	2.10	1:20
3	1: 3.1	18.10	1:3
4	1: 8.4	6.50	1:8
5	1: 2.0	26.40	1:2
6	1: 9.9	5.45	1:10
7	1: 12.3	4.40	1:12
8	1: 22.2	2.35	1:20
9	1: 11.6	4.55	1:12
10	1: 3.1	17.55	1:3
11	1: 8.4	6.50	1:8
12	1: 10.4	5.30	1:10
13	1: 16.4	3.30	1:16
14	1: [illegible]	[illegible]	1:2
15	1: 2.0	26.15	1:2
16	1: 3.0	18.20	1:3
17	1: 17.2	3.20	1:16
18	1: 12.3	4.40	1:12
19	1: 11.8	4.50	1:10
20	1: 8.4	6.50	1:8
21	1: 19.6	2.55	1:20

Sample #	GLS	H or V	DEG.	
22 1	1: 6.5	H	8.45	1:7
23 6	1: 8.1	H	7.05	1:9
24 3	1: 14.0	H	4.05	1:12
25 10	1: 8.1	H	7.05	1:15
26 8	1: 6.6	V	8.40	1:17 (H) 1:9 (V).
27 9	1: 4.7	H	12.00	1:14
28 5	1: 8.1	H	7.00	1:12
29 2	1: 4.5	H	12.35	1:7
30 7	1: 6.4	H	8.55	1:12
31 4	1: 9.4	H	6.05	1:9

Practice	GLS
1	1:
2	1:
3	1:
4	1:
5	1:
6	1:
7	1:
8	1:
9	1:
10	1:

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: D

Date: 8-9-99

Organization:

Brief description of measurement equip. and technique used:

USE RULER & TRIANGLE. TECHNIQUE USED: SET TRIANGLE TO A HIGH SLOPE THEN MOVE TRIANGLE BACK & FORTH LOOKING FOR HIGHER LINES. IF HIGHER FOUND, READJUST TRI THEN CONTINUE/REPEAT. SAME TECHNIQUE FOR VERT & HORIZ.

Sample #	GLS	Sample #	GLS	H or V
1	1: 12	22	1: 5	H
2	1: 3	23	1: 10	H
3	1: 8	24	1: 6	V
4	1: 19	25	1: 8	H
5	1: 10	26	1: 8	H
6	1: 14	27	1: 8	H
7	1: 2	28	1: 5	H
8	1: 2	29	1: 6	H
9	1: 3	30	1: 7	H
10	1: 9	31	1: 8	H
11	1: 15			
12	1: 10	Practice	GLS	
13	1: 12	1	1:	
14	1: 19	2	1:	
15	1: 17	3	1:	
16	1: 12	4	1:	
17	1: 2	5	1:	
18	1: 12	6	1:	
19	1: 8	7	1:	
20	1: 4	8	1:	
21	1: 16	9	1:	
		10	1:	

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: ε

Date: aug 9 '99

Organization:

Brief description of measurement equip. and technique used:

Sample #	GLS		Sample #	GLS	H or V	
1	1: 3		22	1: 11	H	
2	1: 9		23	1: 7	H	
3	1: 10		24	1: 11	H	
4	1: 12		25	1: 8	H	
5	1: 13		26	1: 7	H	
6	1: 6		27	1: 5	H	
7	1: 16		28	1: 6	H	
8	1: 12		29	1: 11	H	
9	1: 9		30	1: 10	H	
10	1: 4		31	1: 9	H	
11	1: 10					
12	1: 4		Practice	GLS		
13	1: 13		1	1:		
14	1: 19		2	1:		
15	1: 8		3	1:		
16	1: 13		4	1:		
17	1: 14		5	1:		
18	1: 4		6	1:		
19	1: 8		7	1:		
20	1: 5		8	1:		
21	1: 12		9	1:		
			10	1:		

F

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: F

Date:

Organization:

Brief description of measurement equip. and technique used:

6" SCALE & A PEN

Sample #	GLS			Sample #	GLS	H or V		
1	1: 18			22	1:8	H		
2	1: 9			23	1: 15	H		
3	1: 3			24	1: 12	V		
4	1: 11			25	1: 11	H		
5	1: 4			26	1: 16	V		
6	1: 8			27	1: 21	H		
7	1: 14			28	1: 12	V		
8	1: 15			29	1: 5	V		
9	1: 11			30	1: 13	V		
10	1: 18			31	1: 12	H		
11	1: 4							
12	1: 9			Practice	GLS			
13	1: 8			1	1:			
14	1: 2			2	1:			
15	1: 11			3	1:			
16	1: 19			4	1:			
17	1: 3			5	1:			
18	1: 2			6	1:			
19	1: 9			7	1:			
20	1: 8			8	1:			
21	1: 13			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: 6

Date:

Organization:

Brief description of measurement equip. and technique used:

12" STRAIGHT-EDGE SCALE

1 SQUARE RISE PER LENGTH OF SQUARES ALONG EDGE

Sample #	GLS	Sample #	GLS	H or V
1	1:9	22	1:8	H
2	1:18	23	1:5	H
3	1:3	24	1:7	H
4	1:2	25	1:5	H
5	1:9	26	1:7	H
6	1:14	27	1:9	V
7	1:11	28	1:6	H
8	1:12	29	1:5	V
9	1:13	30	1:3	V
10	1:22	31	1:6	H
11	1:3			
12	1:10	Practice	GLS	
13	1:8	1	1:	
14	1:2	2	1:	
15	1:7	3	1:	
16	1:3	4	1:	
17	1:2	5	1:	N/R
18	1:10	6	1:	
19	1:15	7	1:	
20	1:9	8	1:	
21	1:16	9	1:	
		10	1:	

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: H

Date: 10-11-99

Organization:

Brief description of measurement equip. and technique used:

6" SCALE, CLEAR GRID

Sample #	GLS		Sample #	GLS	H or V	
1	1: 3		22	1: 7	H	
2	1: 10		23	1: 8	H	
3	1: 2		24	1: 9	H	
4	1: 8		25	1: 9	H	
5	1: 14		26	1: 5	H	
6	1: 10		27	1: 12	H	
7	1: 17		28	1: 8	H	
8	1: 13		29	1: 7	H	
9	1: 2		30	1: 5	H	
10	1: 3		31	1: 4	H	
11	1: 17					
12	1: 10		Practice	GLS		
13	1: 9		1	1: 2		
14	1: 8		2	1: 11		
15	1: 2		3	1:		
16	1: 9		4	1:		
17	1: 10		5	1:		
18	1: 9		6	1:		
19	1: 3		7	1:		
20	1: 24		8	1:		
21	1: 15		9	1:		
			10	1:		

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:

Data Set: I

Date: 10-5-99

Organization:

Brief description of measurement equip. and technique used:

Pick-up a Slope (Angle) From distortion in grid Lines with 6" Scale and part grid Photo Note!! Take your GLS Values Readings in Undistortion grid Line areas For good Readings

Sample #	GLS			Sample #	GLS	H or V		
1	1: 20			22	1: 12	V		
2	1: 6			23	1: 7	H		
3	1: 15			24	1: 7	H		
4	1: 11			25	1: 19	V		
5	1: 11			26	1: 11	H		
6	1: 5			27	1: 14	H		
7	1: 10			28	1: 14	H		
8	1: 6			29	1: 14	V		
9	1: 14			30	1: 7	V		
10	1: 9			31	1: 6	H		
11	1: 15							
12	1: 5			Practice	GLS			
13	1: 12			1 of 2	1: 5	H		
14	1: 20			2 of 2	1: 8	H		
15	1: 10			3	1:			
16	1: 14			4	1:			
17	1: 6			5	1:			
18	1: 12			6	1:			
19	1: 5			7	1:			
20	1: 18			8	1:			
21	1: 13			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: J

Date: 8-17-99

Organization:

Brief description of measurement equip. and technique used:

ESTABLISH A BASE LINE. LOCATE THE POINT OF MAXIMUM DEVIATION. ALIGN STRAIGHTEDGE ALONG ANGLE FROM TRANSITION TO POINT OF MAXIMUM DEVIATION. CHOOSE A LINE AS A POINT OF REFERENCE. COUNT HOW MANY SQUARES, ~~ALONG~~ FROM THAT LINE, ~~TO THE POINT OF M~~ ALONG THE ANGLE OF MAXIMUM DEVIATION, UNTIL THE NEXT ADJACENT LINE IS CROSSED.

Sample #	GLS		Sample #	GLS	H or V	
1	1: 9		22	1: 8	V	
2	1: 17		23	1: 6	V	
3	1: 16		24	1: 10	V	
4	1: 13		25	1: 12	V	
5	1: 10		26	1: 7	V	
6	1: 2		27	1: 11	V	
7	1: 3		28	1: 12	H	
8	1: 15		29	1: 10	V	
9	1: 11		30	1: 18	H	
10	1: 11		31	1: 19	V	
11	1: 15					
12	1: 2		Practice	GLS		
13	1: 3		1	1:		
14	1: 13		2	1:		
15	1: 10		3	1:		
16	1: 18		4	1:		
17	1: 8		5	1:		
18	1: 11		6	1:		
19	1: 2		7	1:		
20	1: 3		8	1:		
21	1: 15		9	1:		
			10	1:		

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:

Data Set: K

Date: 8-21-99

Organization:

Brief description of measurement equip. and technique used:

Sample #	GLS	H	V	Sample #	GLS	H or V
1	1: 11	✓		22	1: 15	V
2	1: 8		✓	23	1: 13	V
3	1: 23		✓	24	1: 20	V
4	1: [illegible]		✓	25	1: 10	V
5	1: 2	✓		26	1: 12	V
6	1: 10		✓	27	1: 18	V
7	1: 3		✓	28	1: 7	V
8	1: [illegible]		✓	29	1: 11	V
9	1: 2		✓	30	1: 13	V
10	1: 10		✓	31	1: 11	V
11	1: 19		✓			
12	1: 3		✓	Practice	GLS	
13	1: 9		✓	1 of 2	1: 2	V
14	1: 16		✓	2 of 2	1: 15	V
15	1: 12		✓	3	1:	
16	1: 17		✓	4	1:	
17	1: 8		✓	5	1:	
18	1: 8		✓	6	1:	
19	1: [illegible]		✓	7	1:	
20	1: 2		✓	8	1:	
21	1: 3		✓	9	1:	
				10	1:	

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:

Data Set: L

Date: 8-16-99

Organization:

Brief description of measurement equip. and technique used:

Strait edge & clear template on ~~Practice~~ BH 8-16-99 Practice
strait edge on all Actual photos
strait Edge and template on computer Generated

Sample #	GLS			Sample #	GLS	H or V		
1	1: 4	H		22	1: 13	H		
2	1: ~~24~~ 17 BH	H		23	1: 12	V		
3	1: 9	H		24	1: 12	H		
4	1: 10	H		25	1: 11	V		
5	1: 4	H		26	1: 17	H		
6	1: 14	H		27	1: 5	H		
7	1: 10	H		28	1: 16	V		
8	1: 2	H		29	1: 12	H		
9	1: 3	H		30	1: 30	H		
10	1: 8	H		31	1: 8	V		
11	1: 18	H						
12	1: 12	~~H~~ H BH 8-16-99		Practice	GLS			
13	1: 18	H		#1 1	1: 2	H		
14	1: ~~30~~ 17 BH	H		#1 2	1: 2	H		
15	1: ~~25~~ 18 BH	H		#1 3	1: 8	H		
16	1: 18	H		#2 4	1: 13	H		
17	1: 4	H		#2 5	1: 1:11	H		
18	1: 8	H		#2 6	1: 21	H		
19	1: 4	H		7	1: ~~8~~ BH 8-16-99			
20	1: 16	H		8	1:			
21	1: 9	H		9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: M

Date: Aug 16 1999

Organization:

Brief description of measurement equip. and technique used:

Using straight edge, Find and follow distortion, go into non-distorted area and count the grid slope.

Sample #	GLS			Sample #	GLS	H or V		
1	1: 10			22	1: 16	H		
2	1: 15			23	1: 9	H		
3	1: 12			24	1: 8	H		
4	1: 2			25	1: 13	V		
5	1: 11			26	1: 13	H		
6	1: 15			27	1: 16	H		
7	1: 3			28	1: 15	V		
8	1: 9			29	1: 13	H		
9	1: 2			30	1: 11	H		
10	1: 14			31	1: 20	H		
11	1: 8							
12	1: 3			Practice	GLS			
13	1: 9			1	1:			
14	1: 12			2	1:			
15	1: 2			3	1:			
16	1: 16			4	1:			
17	1: 13			5	1:			
18	1: 10			6	1:			
19	1: 3			7	1:			
20	1: 10			8	1:			
21	1: 8			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:	Data Set: N
Date:	
Organization:	

Brief description of measurement equip. and technique used:

Sample #	GLS
1	1: 10
2	1: 21
3	1: 3
4	1: 12
5	1: 9
6	1: 2
7	1: 17
8	1: 3 or 4
9	1: 13
10	1: 2
11	1: 8
12	1: 17
13	1: 19
14	1: 10
15	1: 21
16	1: 9
17	1: 3
18	1: [illegible]
19	1: 9
20	1: 13
21	1: 2

Sample #	GLS	H or V
22	1: [illegible]	H
23	1: 20	H
24	1: 8	H
25	1: 7	H
26	1: 11	V
27	1: 18	H
28	1: 14	H
29	1: 26	H
30	1: 16	H
31	1: 13	H

Practice	GLS
1	1:
2	1:
3	1:
4	1:
5	1:
6	1:
7	1:
8	1:
9	1:
10	1:

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:

Data Set: 0

Date: 8/17/99

Organization:

Brief description of measurement equip. and technique used:

Using Venco Detailer 3500 Draftsman sq., Align Photo True Grid Line To zero. Align Horiz. or Vert. Leg of ~~sq~~ sq. to most distorted Line read degrees/mins. convert. To Line slope

Sample #	GLS			Sample #	GLS	H or V		
1	1: 2	±		22	1: 6	H ~~No True Grid Lines To Align Photo~~		
2	1: 21			23	1: 14	H ~~" " "~~		
3	1: 11			24	1: 19	H		
4	1: 10			25	1: 7	H		
5	1: 3			26	1: 5 ~~No True Grids For Photo Align~~	H		
6	1: 8			27	1: 13	H		
7	1: 16			28	1: 12 ~~No Reference Grid~~	H		
8	1: 3			29	1: 21	H		
9	1: ~~8~~ 15			30	1: 9 ~~No True Reference Grid~~	H		
10	1: 8			31	1: 8	H		
11	1: 10							
12	1: 20			Practice	GLS			
13	1: 12			1	1: 2	H		
14	1: 2			2	1:			
15	1: 15			3	1:			
16	1: 8			4	1:			
17	1: 10			5	1:			
18	1: 2			6	1:			
19	1: 3			7	1:			
20	1: 21			8	1:			
21	1: 12			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: Data Set: P

Date:

Organization:

Brief description of measurement equip. and technique used:

DRAFTING TABLE AND VEMCO ELBOW-TYPE DRAFTING SCALE. LINE PHOTO BY OUTSIDE TRUE GRID LINE - MOVE SCALE TO PARALLEL OF CURVED LINES AND TAKE READINGS OF WORST AREA.

Sample #	GLS			Sample #	GLS	H or V		
1	1: 8			22	1: 14	H		
2	1: 16			23	1: 11	H		
3	1: 18			24	1: 9	V		
4	1: 11			25	1: ~~8~~	~~H~~	T.S NO BASELINE	1:14 H
5	1: 9			26	1:		1:13	V
6	1: 2			27	1: 8	H		
7	1: 3			28	1:		1:10	H
8	1: 3			29	1:		1:11	H
9	1: 2			30	1: 12	V		
10	1: 14			31	1:		1:10	H
11	1: 11							
12	1: 9			Practice	GLS			
13	1: 8			1	1:			
14	1: 18			2	1:			
15	1: 9			3	1:			
16	1: 3			4	1:			
17	1: 14			5	1:			
18	1: 8			6	1:			
19	1: 2			7	1:			
20	1: 19			8	1:			
21	1: 12			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:	Data Set: Q
Date:	
Organization:	

Brief description of measurement equip. and technique used:

Drafting table + Detailer 3500

Sample #	GLS			Sample #	GLS	H or V		
1	1:8			22	1:10	H		
2	1:16			23	1: 5	H		
3	1:22			24	1:10			
4	1:11			25	1:10	H		
5	1:3			26	1:9	H		
6	1:13			27	1:5	H		
7	1:2			28	1:7	H		
8	1:22			29	1:6	H		
9	1:11			30	1:7			
10	1:3			31	1:10	H		
11	1:16							
12	1:13			Practice	GLS			
13	1:9			1	1:			
14	1:3			2	1:			
15	1:4			3	1:			
16	1:18			4	1:			
17	1:9			5	1:			
18	1:10			6	1:			
19	1:19			7	1:			
20	1:13			8	1:			
21	1:2			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name: | Data Set: R

Date: 12-10-99

Organization:

Brief description of measurement equip. and technique used:

Transparent foils with grid slopes between 1:2 and 1:20 marked together with Horiz/Vertical datum lines. Foil is slid over sample under test until a match is obtained.

Sample #	GLS			Sample #	GLS	H or V		
1	1: 3			22	1: 14	H		
2	1: 18			23	1: 15	H		
3	1: 2			24	1: 8	✓		
4	1: 8			25	1: 14	H		
5	1: 19			26	1: 10	H		
6	1: 10			27	1: 12	H		
~~7~~ 8	1: 16			28	1: 10	✓		
8 9	~~1: 3~~			29	1: 1.5	✓		
9 10	1: 19			30	1: 1.5	H		
10 11	1: 14			31	1: 1.8	✓		
11 12	1: 2							
12 13	1: 10			Practice	GLS			
13 14	1: 8			1	1:			
14 15	1: 14			2	1:			
15 16	1: 16			3	1:			
16 17	1: 18			4	1:			
~~17 18~~	~~1: 16~~			5	1:			
18	1: 2			6	1:			
19	1: 3			7	1:			
20	1: 19			8	1:			
21	1: 14			9	1:			
				10	1:			

ASTM Grid Line Slope Interlaboratory Study Data Sheet

Name:

Data Set: S

Date: 12-10-99

Organization:

Brief description of measurement equip. and technique used:

Transparent Foils with grid slopes between 1:2 & 1:20 marked together with Horiz/Vertical datum lines Foil is slid over sample under test until a match is obtained

Sample #	GLS			Sample #	GLS	H or V		
1	1: 10			22	1: 10	H		
2	1: 12			23	1: 18	H		
3	1:3			24	1: 5	H		
4	1:20			25	1:20	V		
5	1: 19			26	1: 5	H		
6	1: 2			27	1: 15	V		
7	1: 18			28	1: 20	H		
8	1: 15			29	1: 8	H		
9	1: 3			30	1: 17	V		
10	1: 19			31	1: 19	H.		
11	1: 20							
12	1: 2			Practice	GLS			
13	1: 15			1	1:			
14	1: 12			2	1:			
15	1: 2			3	1:			
16	1: 3			4	1:			
17	1: 16			5	1:			
18	1: 14			6	1:			
19	1: 15			7	1:			
20	1: 17			8	1:			
21	1: 10			9	1:			
				10	1:			